SP-F10 Evaluation of Project Effects on Salmonids and Their Habitat in the Feather River Below the Fish Barrier Dam

October 25, 2002

1.0 Introduction/Background

Ongoing operation of the Oroville Facilities influences flows and water temperatures in the Feather River downstream of the Fish Barrier Dam. These influences vary both seasonally and geographically, and can act either independently or in combination to affect flow, water temperature, floodplain habitat, instream habitat, shaded riverine aquatic (SRA) habitat, coarse sediment supply and other instream conditions in the Feather River.

Salmonids in the Feather River below the Fish Barrier Dam include Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). The timing of the lifecycles of each of these races or species is different. Therefore, at any given time, project operations potentially affect different lifestages (e.g., adult immigration, spawning and incubation, juvenile rearing, emigration) of the various salmonids and their habitat (e.g., spawning and rearing habitat). To account for seasonal and geographical differences in potential project effects, and to address such effects in a comprehensive fashion, project effects on Chinook salmon and steelhead and their habitat in the Feather River will be evaluated species-by-species, and lifestage-by-lifestage. Additionally, tasks and subtasks developed in this study plan (SP-F10) to address lifestage specific potential project effects on steelhead also will serve to address lifestage specific potential project effects on rainbow trout (*O. mykiss*) and brown trout (*Salmo trutta*). During the time steelhead are in freshwater, steelhead and rainbow trout have similar ecological requirements (McMichael et al. 1977) and utilize similar habitat types (McMichael et al. 1992, 1994; Pearsons et al. 1993), with the possible exception of brown trout and the adult lifestage of rainbow trout. Additionally, as members of the same species, it is not possible to visually differentiate Feather River steelhead from Feather River rainbow trout in the field. Because management decisions that would benefit steelhead would also benefit rainbow trout, both races of *O. mykiss* will be treated as one unit under this study plan.

Studies listed under Section 5.0 of this study plan have provided information on the different lifestages of Feather River salmonids, as well as on the potential effects of the ongoing operation of the Oroville Facilities on their habitat, distribution and abundance. Brief descriptions of information derived from those studies are provided in the introductory paragraphs to each of the tasks envisioned for this study plan.

2.0 Study Objectives

The overall objective of this study is to evaluate the potential effects of ongoing Oroville Facilities operations on Chinook salmon, steelhead, rainbow trout, and brown trout and their habitat in the Feather River below the Fish Barrier Dam.

Each of the tasks of this study has a particular objective, which, in general, addresses the evaluation of the influence of the operations of the Oroville Facilities on a particular variable (e.g., flow, temperature, suitable habitat) that in turn may affect a particular lifestage of the Feather River salmonids. These individual objectives and their associated task are provided below.

- Evaluate the influence of Oroville Facilities operations on Feather River attraction flows and their effects on salmonids in the Feather River below the Fish Barrier Dam (Task 1A);
- Evaluate the influence of Oroville Facilities operations on Feather River attraction water temperatures and their effects on salmonids in the Feather River below the Fish Barrier Dam (Task 1B);
- Evaluate flow-related physical impediments in the Feather River below the Fish Barrier Dam (Task 1C);
- Evaluate the influence of Oroville Facilities operations water temperature related effects on pre-spawning salmonid adult production (Task 1D);
- Evaluate the influence of Oroville Facilities operations on early-upmigrant adult Chinook salmon holding habitat and habitat use patterns (Task 1E);
- Evaluate spawning and incubation substrate availability and suitability for salmonids in the Feather River (Task 2A);
- Evaluate flows and flow effects on the spawning distribution of salmonids in the Feather River (Task 2B);
- Evaluate water temperatures and water temperature effects on spawning and incubation of salmonids in the Feather River (Task 2C);
- Evaluate flow-fluctuation effects on redd dewatering in the Feather River below the Thermalito Afterbay river outlet (Task 2D);
- Identify relative abundance and distribution of rearing salmonids in the Feather River and determine habitat characteristics for rearing juvenile salmonids in the Feather River (Task 3A);
- Evaluate Feather River water temperature effects on salmonid juvenile rearing (Task 3B);
- Evaluate flow-fluctuation effects on juvenile stranding in the Feather River (Task 3C);
- Describe relationships between flow and juvenile salmonid abundance and emigration in the Feather River, and evaluate potential flow-related project effects on salmonid juvenile emigration (Task 4A); and Describe relationships between water temperature and juvenile salmonid abundance and emigration, and evaluate potential water temperature-related project effects on salmonid juvenile emigration from the Feather River (Task 4B).

Study results may be used to evaluate future potential operational scenarios and to develop and implement protection, mitigation and enhancement measures (PM&Es) for the salmonid populations in the study area. The study results also will be used by other studies to help assess the project's ongoing effects on California and Federal special status species.

3.0 Relationship to Relicensing/Need for the Study

Potential effects of ongoing project operations on Feather River salmonids include alterations in flow, water temperature, floodplain habitat, instream habitat, SRA habitat, coarse sediment supply, and other in-river conditions. These habitat characteristics and conditions influence the various lifestages (e.g., adult immigration, spawning and incubation, rearing, emigration) of salmonids. Details on the relationships between project operations, affected variable (e.g., flow, temperature, suitable habitat) and potential impact on the various lifestages of Feather River salmonids are detailed under the subtitle **Conceptual Framework** with each task described under Section 5.0 of this study plan.

Section 4.51(f)(3) of 18 CFR requires reporting of certain types of information in the Federal Energy Regulatory Commission (FERC) application for license of major hydropower projects, including a discussion of the fish, wildlife and botanical resources in the vicinity of the project. The discussion needs to identify the potential impacts of the project on these resources, including a description of any anticipated continuing impact for on-going and future operations. This study plan fulfills these requirements, by evaluating potential project effects on salmonids and their habitat in the Feather River below the Fish Barrier Dam.

4.0 Study Area

This study plan (SP-F10) addresses different salmonid lifestages and, therefore, the study area boundaries vary among tasks. Because each subtask varies in geographic scope, the geographic scope and rationale for establishing that scope is detailed within each subtask for the specific evaluation being conducted in that subtask. The upstream extent of all subtasks in this study plan is the Fish Barrier Dam, with the exception of Task 1E which includes habitat evaluation between the Thermalito Diversion Dam and the Fish Barrier Dam, to evaluate potential PM&Es as input to SP-F15. The greatest downstream extent of any subtask in this study plan is the confluence of the Feather and Sacramento Rivers. Study plans approved by the Environmental Work Group define the limits of the study area. If initial study results indicate that the study area should be expanded or contracted, the Environmental Work Group will discuss the basis for change and revise the study area as appropriate.

5.0 General Approach

The study plan is divided into four primary tasks. Each task evaluates potential ongoing Oroville Facilities operations effects on a specific lifestage of salmonids within the study area. Each task also contains at least one component requiring the review and integration of existing information.

Review and integration of existing information includes both site-specific data, and other information. Reviews involving the evaluation of site-specific data generated by previous surveys will focus on assessing the fulfillment of the study objective, the experimental design utilized, the applicability of the methodologies/sampling techniques used to obtain data, the completeness of the data set, the reliability of data collected based on the type of methodologies and experimental design used, the applicability of the statistical analysis performed on data, the value of the statistical analysis (e.g., are the analyses appropriate given the type of data, sample size, variance), and the accuracy of the conclusions drawn from the study. Reviews evaluating applicability of information collected from other study sites will focus on the degree of similarity between the study site and the Feather River, and the degree of similarity between environmental parameters documented in the study and the environmental conditions known to exist in the Feather River. Review of available information may include, but is not limited to, the following existing sources:

- California Department of Water Resources-Environmental Services Office (DWR-ESO). Study of the abundance and timing of emigration of juvenile salmon and steelhead; includes data from operation of rotary screw traps (RST), fyke nets, and seining. Ongoing since 1996.
- California Department of Fish and Game (DFG). Surveys providing annual population estimates for fall-run Chinook salmon and Chinook salmon exhibiting spring-run life-history returning to spawn; various survey methods. Fall from 1953-1999. Continued from 1999-present by DWR.
- DWR-ESO. Study of the distribution and habitat use (including riparian habitat use) of juvenile Chinook salmon and steelhead (snorkeling observations) (March through August) on the Feather River between the Fish Barrier Dam and Gridley Bridge. Begun in Spring of 1999.
- DWR-ESO and DFG. Records of implanting coded wire tags (CWT) in juvenile hatchery salmon since 1975. DWR-ESO began tagging "wild" juvenile salmon in 1998. The tags are recovered through ocean and inland harvest recovery programs coordinated by DFG and new analysis of tag recoveries underway through contract with California State University, San Francisco (CSUSF) Romberg Tiburon Center and U.S. Fish and Wildlife Service (USFWS).
- DWR-ESO. Studies of steelhead and Chinook salmon habitat use; information includes depth, current velocity, substrate, in-stream cover, and over-head cover. 1999 and 2000.
- DWR-ESO. Mapping studies (1999) and Instream Flow Incremental Methodology (IFIM) study (1992). Delineation of riffles, pools, glides and backwater habitats on aerial photographs for the area from the Fish Barrier Dam to the Gridley Bridge. IFIM study targeted Chinook salmon, steelhead and American shad; thirty-two transects were selected for analysis between the Fish Barrier Dam and Honcut Creek.
- DWR Northern District. Feather River gravel condition reports (1982, 1996), including 1982 Feather River Spawning Gravel Baseline Study.
- Historic stream flows in the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet and below Thermalito Afterbay river outlet.
- DWR-ESO. Hourly temperature recordings at 20 sites between the Thermalito Diversion Dam and Live Oak (began in 1997 but records are incomplete until 1999).
- U.S. Geological Survey (USGS). Temperature records at gage downstream from Oroville Dam, 1958 to 1992.
- DWR. Continuous water temperature records (at gage downstream from Oroville Dam) since 1995.
- DWR Oroville Field Division (OFD). Mean daily water temperature records at the Feather River Fish Hatchery since initiation of hatchery operations and Robinson Riffle since July 31, 2000.
- USGS. Records of maximum and minimum daily water temperatures at the Thermalito Afterbay river outlet. October 1968 through September 1992. Since 1992, only mean daily water temperature data is available from OFD.
- University of California at Davis (UC Davis). River temperature model developed under contract with DWR-ESO. 2000.
- UC Davis. Laboratory study on steelhead growth and thermal biology performed under contract with DWR-ESO. 1999.
- California State University, Chico (CSUC). Study of macro-invertebrate food base available for rearing salmon and steelhead. Ongoing study-began in Fall 2000 and will continue for two years. Funded by DWR-ESO.
- DWR-ESO. Study of stranding and redd dewatering; will identify potential stranding areas between the Fish Barrier Dam and Honcut Creek, and attempt to quantify salmonid losses. Ongoing study initiated in Fall 2000.

- DWR and U.S. Bureau of Reclamation (USBR). Biological Assessment – Effects of the Central Valley Project and State Water Project on Steelhead and Spring-run Chinook Salmon. November 2000.
- National Marine Fisheries Service (NMFS). Endangered Species Act-Section 7 Consultation Biological Opinion. Central Valley Project (CVP) and State Water Project (SWP) Operations, January 1, 2001 through March 31, 2002. 2001.
- USFWS. fish studies.
- Central Valley Project Improvement Act (CVPIA). Working Paper and Restoration Plan.
- DFG. Plan for Action.
- DFG. Plan for Restoration of Fish.
- DFG and UC Davis. Genetic studies by Bodega Marine Lab.
- Yuba River studies related to fish.
- DFG and USFWS. Study of juvenile salmonid downstream migration including rotary screw traps in the Sacramento River, fyke traps, midwater trawl and Kodiak trawl studies in the Sacramento River, Broad Slough, Konker Bay, Carquinez Strait, San Pablo Bay, and San Francisco Bay. Additional associated reports available from the San Francisco Bay – Sacramento and San Joaquin Rivers Delta (Bay/Delta) Region.
- DFG. An Evaluation of Fish Populations and Fisheries in the Post-Oroville Project Feather River. 1977.
- DFG and other resource agencies. Information from reports, fish surveys and creel census surveys (e.g., Painter et al. 1977).
- DWR. Information and results provided by FERC Relicensing studies (see section 7.0 Coordination and Implementation Strategy.

If initial study results indicate that the methods and tasks should be modified, the Environmental Work Group will discuss the basis for change and revise the study plans as appropriate.

Detailed Methodology and Analysis Procedures

<u>Task 1—Evaluation of Project Effects on the Upstream Migration of Adult Salmonids in the Feather River Below the Fish Barrier Dam</u>

Operation of the Oroville Facilities affects the flow and water temperature regime in the Feather River below the Fish Barrier Dam. Flow and water temperature are two important factors influencing the ability of adult salmonids to migrate upstream and influencing pre-spawning adult salmonids. Adequate flows are necessary to provide sufficient attraction flows and to allow fish passage past potential physical impediments. Water temperatures may provide attraction cues and influence pre-spawning adult survival and egg viability.

Task 1 will evaluate the effects of Feather River flows and water temperatures on attraction of migrating salmonids (Tasks 1A and 1B, respectively). Additionally, this task will evaluate the effects of flow on adult upstream passage (Task 1C), the effects of water temperature on pre-spawning adult salmonids and subsequent reproduction (Task 1D), and the effects of water temperature on early up-migrant adult Chinook salmon holding habitat and use patterns (Task 1E).

Task 1A—Evaluate the influence of Oroville Facilities operations on Feather River attraction flows and their effects on salmonids in the Feather River below the Fish Barrier Dam

Attraction flows may influence the upstream migration and pre-spawning physiology of adult salmonids in the Feather River below the Fish Barrier Dam. The release of water from Lake Oroville can affect the timing of salmonid entry into the river. Insufficient attraction flows may delay entry into the upstream areas of the river and flows also may result in an increased straying of adult salmonids destined (native) for the Feather River to stay in the Sacramento River, or to migrate into the Yuba River.

Feather River Fish Hatchery (FRH) Chinook salmon have been documented as straying throughout the Central Valley for many years (Kelly and Dettman 1987) and have intermixed with wild-spawned spring-run and fall-run Chinook salmon in the upper Sacramento River, although the extent of hybridization has not been definitively documented (DWR and USBR 2000). Straying is of concern because of its potentially negative effects on the genetic distinctiveness of Chinook salmon populations, and its potential to reduce the genetic variability of wild Central Valley Chinook salmon. Instances of straying of CWT fish from other river systems into the Feather River will also be reported under this subtask and subtask 1B.

Estimating the staying rates of wild salmonids is difficult and attempts to quantify rates have produced a great range (Quinn 1993). For instance, a review by CDFG and NMFS (2001) reports a range of natural straying rates between <1% for sockeye in British Columbia (Foerster 1968) and over 50% for chum in British Columbia (Tallman and Healey 1994). In addition, estimates of straying rates may largely depend on study design and terminology definitions (CDFG and NMFS 2001). Salmonid straying may also vary with environmental conditions (Leider 1989; Milner and Bailey 1989). Studies of hatchery Chinook salmon from the Lewis River estimated 9.9% straying (Quinn et al. 1991), while estimates of straying of hatchery Chinook salmon from the Cowlitz River range from 1.4% to 28.5% (Quinn et al.1991, Quinn and Fresh 1984). Straying may be influenced by attraction flows, but may also be influenced by other factors including hatchery planting locations. Previous straying analysis of FRH Chinook salmon has shown that when fish were released in the Feather River, the mean straying rate (number of strays/freshwater escapement) was estimated to be 0.073, with upper and lower 95% confidence limits of 0.006 and 0.205, while the mean straying rate for FRH Chinook released in the estuary was estimated to be 0.691, with upper and lower 95% confidence limits of 0.557 and 0.810 (Cramer 1990). A similar trend was seen in an analysis by Kelley and Dettman (Kelly and Dettman 1987), which estimated that straying of FRH Chinook salmon is 0.08 when releases are made in the Feather River and 0.53 when releases are made in the estuary. Cramer (1990) suggests that straying has dramatically increased since hatchery fish have been trucked to the estuary and bay for release. Because straying is possibly influenced to a greater extent by hatchery planting practices than by flows, the analysis presented in this task regarding the relationship of attraction flows to straying is qualified by the anticipation that it could be possible that the relationship between flows and straying may not detectable given other, possibly stronger, factors influencing straying. Every effort will be made to utilize data sets, which limit the possible effects of release location by comparing sets of data with common release locations, when possible.

Attraction flows will be evaluated for all months of the year for each year and month in which straying data is available. The upstream migration period for the target salmonids includes September through December for fall-run Chinook salmon (Sommer et al. 2000), March through June for Chinook salmon exhibiting spring-run life-history (Sommer et al. 2000), and September through January for steelhead (DWR 2001). Adult salmonids migrating upstream in the Sacramento River might not be attracted into the Feather River if flows in the Feather River are low relative to Sacramento River flows. Similarly, adult salmonids migrating upstream in the Feather River might be attracted into the Yuba River if flows in the Feather River are low relative to Yuba River flows.

Conceptual Framework. The ongoing operation of Oroville facilities may affect Feather River attraction flows, expressed as flow indices (see below), resulting in straying of Feather River salmonids into the upper Sacramento River and tributaries, and the Yuba River.

Flow Indices. A data review will be performed to determine the difference in river discharge between the Feather River and the upper Sacramento River, and between the Feather River and the Yuba River for each month. The data review will require contact with USGS and the California Data Exchange Center (CDEC) and an evaluation of the quality of the available records. The river discharge data used in evaluating the differences between Feather River and the upper Sacramento River flows, and between Feather River and Yuba River flows will include years following the construction of the Oroville Facilities (1968) for each month. Additional confluences upstream of the Feather River-Sacramento River confluence, such as the Feather River-Bear River confluence may be included in this analysis if existing flow and straying data is sufficient to support such an analysis.

Prior to evaluating the differences in river discharge or flow between the Feather River and the upper Sacramento River, and between the Feather River and the Yuba River, the available time series of flow records will be inspected for consistency, data gaps and recording errors. In selecting adequate time series of flow records for the two comparisons, the locations of the recording gage stations and the period of continuous record will be considered. For example, Feather River and Yuba River gage stations upstream of, and closest to, the confluence of the Feather and Yuba rivers with the longest series of continuous flow records would be preferred for the evaluation of the flow differences between the Feather River and the Yuba River. The USGS gage station near Gridley (USGS 11407150) and the gage station at the Thermalito Afterbay river outlet (USGS 11406920) have gathered daily flow records on the Feather River since 1964 and 1967, respectively. Both stations generated time series long enough to be compared with the 1943 to present time series of flow records gathered at the USGS gage station near Marysville for the Yuba River (USGS 11421000). The Gridley gage station is closer to the confluence of the Feather and Yuba rivers than the Thermalito Afterbay station. Consequently, the Gridley gage is more likely to produce flow measurements closer to the flows perceived by upstream migrating salmonids approaching the confluence of the Feather and Yuba rivers. However, the consistency, accuracy and extent of data gaps for both the Gridley and Thermalito Afterbay flow time series will be evaluated before making a final decision on which flow time series, if any, is most appropriate for this analysis.

Once adequate flow time series records for the Sacramento, Yuba and Feather Rivers have been selected, flow indices will be calculated as the ratio of Feather River flows to upper Sacramento River flows, and as the ratio of Feather River flows to Yuba River flows. The flow ratios (flow indices) will serve as the measure of differences in flows between rivers and will be calculated for each month and year in which straying data is available. Various expressions of flow (mean daily, mean monthly, peak daily, etc.) may be used to construct the indices that will be utilized in the analyses (see *Analyses* below).

Straying Indices. The Feather River Fish Hatchery has been releasing coded-wire tagged juvenile spring-run sized Chinook salmon for experimental purposes since 1976, fall-run Chinook salmon since 1972 and steelhead juveniles since 1983. In order to determine the amount of straying of Feather River salmonids into other waterbodies, Feather River Fish Hatchery coded-wire tag (CWT) returns will be examined. CWT return data, including release location, age at recovery, recovery site, and physiological measurements such as fish sex, length and weight will be compiled and summarized in SP-F9. The number of reported Feather River Fish Hatchery CWT recoveries will be sorted by species, year, month and site of recovery, accounting for site sampling intensity or other measure of site recovery effort, when possible. Activities undertaken in this study plan (SP-F10) will use the best available information, and will be closely coordinated with activities undertaken under SP-F9 to maximize efficiency and data utility, and to avoid redundant efforts.

Straying indices for Feather River salmonids will be calculated in SP-F9 (as described below) and SP-F10 will investigate the relationship between flow and straying using the straying indices provided by SP-F9. For instance, an index for Feather River salmonids straying into the Upper Sacramento River and its tributaries will be calculated as the ratio of the number of Feather River Fish Hatchery CWTs recovered at recovery sites located on the Upper Sacramento River and its tributaries upstream of the Feather-Sacramento confluence, to the number of Feather River Fish Hatchery CWTs recovered at sites upstream of the Feather-Sacramento confluence, including recovery sites on the Feather River. Similarly, an index for Feather River salmonids straying into the Yuba River will be calculated as the ratio of the number of Feather River Fish Hatchery CWTs recovered at recovery sites located on the Yuba River, to the number of Feather River Hatchery CWTs recovered at sites on both the Yuba River and Feather River upstream of the Yuba-Feather confluence. In addition to calculation of straying indices for Feather River fish, instances of straying of fish from other river systems into the Feather River obtained from SP-F9 and the CWT blitz will be reported in this subtask.

Straying indices will be calculated for a given year, month and species, contingent on data quality and availability. Straying data will be evaluated for its applicability to statistical comparisons (including data gaps and temporal resolution of data for compatibility with the temporal resoluation of flow data). It may not be possible to create a straying index on a monthly basis due to the method of CWT recovery documentation. In such cases, straying indices would be calculated on an annual basis. In the straying index calculations, all possible recovery sites may be accounted for (e.g., instream fishing sites, spawning grounds and other hatcheries, such as the Tehama-Colusa Fish Facility, the Coleman National Fish Hatchery or the Livingston Stone National Fish Hatchery). If reports of level of effort for some recovery sites, such as instream fishing sites, are not available, and therefore no adjustment can be made for recovery effort, CWT returns at hatcheries may be the primary source of CWT return data used for this analysis.

Analyses. After the flow indices and straying indices have been calculated and examined to detect temporal trends or other patterns, the relationship between the two indices will be studied, contingent on the quality and extent of both index series. Plots of the straying indices as a function of the flow indices will be constructed and examined. A lack of significant correlation would indicate the lack of any effect of Feather River flows influencing attraction or straying of Feather River salmonids that is detectable using the existing data. If a correlation between straying and flow indices is found, the potential relationships between both indices will be explored, as described below.

Both linear (e.g., $I_{STRAY} = a + \beta \times F_{FEA/SAC}$) and nonlinear (e.g., $I_{STRAY} = e^{(a+\beta \times F_{FEA/SAC})}$) models will be used to describe the relationship between flow and straying indices if the two variables are correlated. The models will be fitted using traditional minimum least squares techniques to obtain estimates of the model parameters (i.e., α and β). The goodness-of-fit of the models will be assessed and model fits will be evaluated to select the best model for the data. The equation describing the best fitted model, then, will be used as a tool to evaluate the potential effects of flows modeled by the Engineering and Operations Work Group on the straying of Feather River salmonids. The model produced by the Engineering and Operations Work Group, described in study plan SP-E1.1—*Statewide Operations Model Development* and SP-E1.2-*Local Operations Model Development,* will generate the output of long-term flows that will be used to calculate flow index values $F_{FEA/SAC}$ for a variety of operations scenarios. These new values will then be used to predict expected Feather River straying index values using the best-model equation describing the relationship between Feather River straying index and flow index. If a correlation between flow indices and straying indices is detected, but the correlation is not significant ($p<0.05$), a power analysis will be conducted to determine the number of data points in the time series required to detect a significant correlation assuming the observed variability in the data. This analysis could be used to recommend a long-term monitoring program to further investigate the effects of flow on straying in the Feather River.

Task 1B—Evaluate the influence of Oroville Facilities operations on attraction water temperatures and their effects on salmonids in the Feather River below the Fish Barrier Dam

Water temperature plays a significant role relative to the timing of upstream migration of adult salmonids (DWR and USBR 2000). Adult salmonids are transiently exposed to the warmwater temperatures of the Delta and lower reaches of the Sacramento River before entering and ascending to cooler upstream reaches of the Feather River. Under current conditions, exposure to the cooler waters of the Feather River is dependent largely on the operations of the Oroville-Thermalito complex including regulation of flows and associated water temperatures. Although specific requirements have not been established for the Feather River, water temperatures of less than 65ºF have been recommended for upstream migrating Chinook salmon in the Central Valley (DWR and USBR 2000). Moreover, pre-spawning Chinook salmon appear to achieve bioenergetic optimization through behavioral thermoregulation or active selection of cooler water temperatures, as shown by a study on the movement of radio-tagged salmonids (Berman and Quinn 1991). When salmonids migrate upstream of the Delta and into lower reaches of the Sacramento River, cooler water temperatures along the upstream migration corridor may attract upstream migrating salmonids, and warmer temperatures may deter upstream migration. If water temperatures encountered by the upstream-migrating salmonids in the Feather River were cooler than those in the upper Sacramento River, Feather River salmonids may be encouraged to continue their migration to their natal spawning grounds in the Feather River, thus decreasing the likelihood of straying into the upper Sacramento River. Similarly, if water temperatures encountered by the upstream-migrating salmonids in the Yuba River were cooler than those in the Feather River, Feather River salmonids may be encouraged to migrate into the Yuba River, thus straying from their natal spawning grounds. Attraction temperatures will be evaluated for all months of the year for each year and month in which straying data is available.

Conceptual Framework. The ongoing operation of Oroville facilities may affect Feather River water temperatures, warming or cooling Feather River waters relative to the water of the upper Sacramento and Yuba rivers. If Feather River waters encountered by Feather River upstream-migrating salmonids are warmer than the waters of the Upper Sacramento River and Yuba River, Feather River salmonids may delay entry in the Feather River or stray into the Yuba River, and the upper Sacramento River or its tributaries. Conversely, cooler Feather River waters may decrease the likelihood of Feather River salmonids delaying upstream migration from the Sacramento River or straying into the upper Sacramento and Yuba rivers.

Water Temperature Indices. A data review will be performed to determine the difference in water temperatures between the Feather River and the upper Sacramento River, and between the Feather River and the Yuba River for the salmonid upstream migration period. The data review will require contact with USGS and the CDEC, and evaluation of the quality of the available records. Existing data may not be sufficient to construct historic water temperature time series for the Feather River, Yuba River and Upper Sacramento River. Therefore, it is anticipated that much of the Feather River water temperature information utilized in this subtask will be derived from output from SP-W6—*Project Effects on Temperature Regime*. For example, the existing Feather River water temperature data collected at the Thermalito Afterbay outlet and compiled by SP-W6 Task 1A, as well as all new water temperature data collected and compiled by SP-W6 Task 1A for stations located downstream of the Thermalito Afterbay outlet will be utilized. The collection of water temperature information for the Yuba River and Upper Sacramento River will require contacts with other agencies, such as the Yuba County Water Agency. Additional confluences upstream of the Feather River-Sacramento River confluence, such as the Feather River-Bear River confluence may be included in this analysis if existing temperature and straying data is sufficient to support such an analysis.

Water temperature indices will be constructed for each month and year in which straying data of sufficient quality is available. These indices will be calculated as: 1) the ratio of Feather River water temperatures to upper Sacramento River water temperatures, and 2) the ratio of Feather River water temperatures to Yuba River water temperatures. Various expressions of water temperature (mean daily, mean monthly, daily maximum, etc.) will be constructed and utilized in the analysis of straying for Feather River salmonids.

Analyses. The index of straying of adult salmonids developed under SP-F9, and the water temperature indices evaluating water temperature differences between the upper Sacramento and Feather rivers, and between the lower Feather and Yuba rivers, will be utilized to evaluate potential relationships between the two types of indices. Contingent upon the quality and extent of both index series, the potential relationships between the two types of indices will be analyzed. Plots of straying indices as function of the water temperature indices will be constructed and examined in search of potential patterns, as described in the analytical procedures detailed in Task 1A.

If the analysis of straying indices and corresponding water temperature indices suggests that straying increases as the water temperature indices increase, and this empirical relationship can be expressed as linear or nonlinear functions, the functions will be used as tools to evaluate the potential effects of water temperatures on the straying of Feather River salmonids. Potential project effects of water temperatures on straying will be evaluated under a variety of operational scenarios by utilizing the model output from study plan SP-E1.5—Feather River Temperature Model Development, which will generate the required long-term water temperatures. The model produced by the Engineering and Operations Work Group will generate the long-term water temperatures expected under current and/or alternative operational scenarios. The simulated Feather River water temperatures will be used to develop mew water temperature indices. The new indices will be used as input to the empirical linear or nonlinear functions to predict the expected straying indexes under the particular operational scenario. Additionally, study plan SP-E6-Downstream Extent of Reasonable

Control of Feather River Temperature, will be used to aid in determining the downstream extent of temperature control by the project and this will facilitate evaluation of the potential effects of the project on attraction temperatures.

Task 1C—Evaluate flow-related physical impediments in the Feather River below the Fish Barrier Dam

Traditionally, flow-related passage impediments to upstream adult salmonid migration are shallow riffles without sufficient flow to allow for passage of adult salmonids. Such a "critical riffle" is defined as a riffle that has the highest probability of becoming a hindrance to salmonid passage with low river flows. However, in the Feather River, sufficient water depth is provided under project operations that the riffles do not inhibit passage based on insufficient water depth. Because of the large number of salmon returning to the upstream-most section of the Feather River (as measured by escapement estimates), flow-related physical impediments to adult upstream passage are not generally considered to occur under current project operations. Although the approach suggested in this subtask, the evaluation of the relationship between flow and passage as measured by escapement, is not a typical critical riffle approach, it meets the needs of the evaluation. Additionally, a critical riffle passage analysis is not warranted given that flow-related passage impediments are not generally thought to block upstream migration of adult salmonids.

Minimum flows in the lower Feather River were established in the August 1983 agreement between DWR and DFG. The agreement specifies that DWR release a minimum of 600 cfs into the Feather River from the Thermalito Diversion Dam for fisheries purposes. For a Lake Oroville surface elevation greater than 733 feet, the minimum in-stream flow requirements on the Feather River below the Thermalito Afterbay outlet (DWR 2001) were stated as:

Percent of normal(1) runoff (%)	Oct.-Feb. (cfs)	Mar. (cfs)	Apr.-Sep. (cfs)
> 55	1,700	1,700	1,000
< 55	1,200	1,000	1,000

(1) Normal runoff is defined 1,942,000 acre-feet, which is the mean (1911 – 1960) April through July unimpaired runoff near Oroville.

In their 2001 Biological Opinion, NMFS suggested that (Page 59) "…Minimum flow releases in the Feather River below the Thermalito Afterbay outlet may drop below the 1,700 cfs minimum flow established in the August 1983 agreement between DWR and DFG…." Although NMFS (2001) also states "…Due to the low number of steelhead spawning outside of the Feather River Hatchery, flows of 600 cfs in the low flow channel are expected to generally provide adequate depths and velocities for upstream passage of migrating adults…".

The available series of annual Chinook escapement abundance estimates and adult steelhead returns to the Feather River Hatchery, indicate that Feather River flows below the Thermalito Afterbay outlet have never been so low as to block upstream migration passage seriously enough to preclude annual escapement to the Feather River spawning grounds and the Feather River Hatchery. Since 1955 for Chinook salmon, and since 1967 for steelhead, adult salmonids have always managed to reach the Feather River Hatchery and spawning grounds. However, potential flow-related physical impediments to upstream passage could have been expressed in a less drastic outcome than "low flow equals zero escapement". The series of annual Chinook escapement abundance estimates and adult steelhead returns to the Feather River Hatchery, and Feather River flows downstream of the Thermalito Afterbay outlet need to be further investigated to identify any consistent temporal pattern among low flow and low escapement years that might be suggestive of potential flow-related physical impediments to upstream passage, and that might justify a detailed study on critical riffles and passage criteria.

Conceptual Framework. The flow regime associated with the ongoing operation of Oroville facilities may impede the passage of salmonids migrating to upstream spawning areas in the Feather River.

Salmonid Escapement Data. Since 1955, DFG has conducted carcass surveys in the Feather River to provide annual abundance estimates of the Chinook salmon spawning escapement. The series of abundance estimates presents a few gaps prior to 1970, but is otherwise complete. Since 2000, DWR has taken the lead in the conduct of carcass surveys and estimation of Chinook salmon spawning escapement. Since 1967, there are records of annual steelhead escapement to the Feather River Hatchery, expressed as total counts of arriving adult steelhead. The available series of annual Chinook salmon spawning escapement estimates and hatchery steelhead counts will be studied to identify the years with lowest escapements.

Flow Data. The average daily flow records recorded at various USGS gage stations on the Feather River (e.g., Feather River at Yuba City USGS 11407700; Feather River at Shanghai Bend USGS 11421700 and USGS 11421701; Feather River at Gridley USGS 11407150) and on the Yuba River (Yuba River near Marysville USGS 11421000) will be collected for all years with Chinook salmon spawning escapement estimates and hatchery steelhead counts. Monthly average, median, minimum and maximum flows and number of days with daily flows below 1,700 cfs will be calculated for months of upstream Chinook migration (March through November) and upstream steelhead migration (November through April).

Analyses. The series of annual Chinook escapement abundance estimates and adult steelhead returns to the Feather River Hatchery, and the series of Feather River flows downstream of the Thermalito Afterbay outlet will be compared to identify any consistent temporal pattern among low flow and low escapement years that might be suggestive of potential flow-related physical impediments to upstream passage. Various procedures and statistical techniques will be used to investigate any potentially emergent pattern.

For instance, the annual Chinook escapement abundance estimates and counts of adult steelhead returning to the Feather River Hatchery will be separated in two series of abundance estimates and counts. Those occurring in years when the monthly average, median or minimum flows during the months of upstream adult migration were lower than 1,700 cfs, and those occurring when the flow metrics were equal or higher than 1,700 cfs. The two series will be compared using an ANOVA approach to test whether means of the abundance estimates and counts occurring when the monthly average, median or minimum flows during the months of upstream adult migration were lower than 1,700 cfs is significantly lower than the means of the complementary series. Moreover, a linear regression approach will be used to detect if there is a strong and significant inverse relationship between the annual Chinook salmon escapement abundance estimates and the annual count of returning steelhead and the number of days when daily flows during the months of upstream adult migration were lower than 1,700 cfs.

If the results from the various analytical approaches suggest that there is a consistent temporal pattern among low flow and low escapement years, the pattern will be taken as evidence that critical passage might be among the factors causing such pattern, and an evaluation of the relationships between flow and the passage of adult salmonid upstream of Shanghai Bench will be initiated. Shanghai Bench, a clay riffle located between RM 26 and 25, has been identified as the mostly likely possible upstream migration impediment in the upstream migration corridor of Feather River salmonids at low flows, knowing that flows are not generally low enough to block upstream migration of adult salmonids. This evaluation will involve the analysis of stage recorder readings from Shanghai Bench at different low flow levels during the upstream migration period, coupled with direct observations on the passage behavior of the adult salmonids at Shanghai Bench.

Task 1D—Evaluate the influence of Oroville Facilities operations on water temperature-related effects on pre-spawning salmonid adult production

Exposure of pre-spawning adult salmonids to elevated water temperature can adversely affect production (e.g., decreased fertilization, increased egg retention, reduced embryo viability and presence of abnormalities in the emergent fry). To evaluate if water temperatures resulting from project operations currently, or may in the future, affect pre-spawning salmonids, a literature review of studies focused on the effects of water temperatures on pre-spawning adult salmonids, and a review of available Feather River water temperature data will be conducted. Available water temperature information for the pre-spawning period (March through December for Chinook salmon and December through April for steelhead) of Feather River Chinook and steelhead will be compared to the results of the literature review on water temperature effects.

Conceptual Framework. The water temperature regime associated with the ongoing operation of Oroville facilities may expose pre-spawning adult salmonids to elevated water temperatures that can adversely affect production (e.g., increased pre-spawning mortality, decreased fertilization, increased egg retention, reduced embryo viability and presence of abnormalities in the emergent fry).

Water-Temperature Effects. A literature review of studies focused on the effects of water temperatures on pre-spawning salmonids will be conducted. The review will include studies based on both laboratory and field experiments, as well as reported observations on water temperature-related effects, dose-response studies, and empirical relationships between water temperature and measures of fish biological performance (e.g., egg-retention percentage, fertilization percentage, embryo viability) and pre-spawning mortality. The reviewed information will be assessed and summarized in species-specific tables showing critical temperature ranges and resulting effect, indicating origin of the information (e.g., laboratory or field experiment, empirical relationship, etc) and comments on reliability of the information source. This review will also include a review of the conditions observed and recommended for holding habitat for early-upmigrating adult Chinook salmon. In addition to water temperature, this review will include water depth, cover and substrate used or preferred by adult salmon during holding for use in Task 1E.

Water Temperature Data. Concurrent to the literature review on water temperature effects, a data review will be performed to gather and organize available monthly and daily water temperature data gathered from SP-W6—Project Effects on Temperature Regime. SP-W6 will compile existing water temperature data into a computer database for access and evaluation. SP-W6 will also collect and report additional water temperature data at the existing monitoring sites, as well as model output for additional sites needed for analyses of potential project effects on the thermal regime of the Feather River below the Fish Barrier Dam. Water temperature data collected by SP-W6 from the Fish Barrier Dam to the Sacramento River will be evaluated against recommended water temperatures from the literature review.

Analyses. Following the literature review, and water-temperature collection and simulation, water temperatures recorded and simulated for the Feather River below Oroville Dam will be compared to recommended water temperatures and critical thresholds cited in the literature review to evaluate the potential for water temperature-related impacts to pre-spawning adults in the Feather River. Separate evaluations will be performed for Chinook salmon (water temperatures from March through December) and steelhead (water temperatures from December through April).

Because uncertainty currently exist regarding absolute identification of suitable water temperatures for upstream migration and pre-spawning adults, different water temperature recommendations obtained from the literature review will be used to evaluate potential water temperature-related effects on pre-spawning salmonids in the Feather River. In addition, because water temperature recommendations for salmonids are often results stemming from laboratory studies, these recommendations must be cautiously applied. Most laboratory studies assess response to primarily one variable (e.g., elevated water temperatures) at a time. Even with greater control on independent variables, results can be biased by experimental conditions as well as the ability of the scientist to interpret results (e.g., studies of water temperature preference sometimes vary when conducted in vertical vs. horizontal temperature gradients). Confinement in experimental containers can itself cause stress. Conclusions also depend on interpretation of data from different kinds of methods (Environmental Protection Agency (EPA) 1999). Therefore, to avoid relying on a single water temperature recommendation that may be biased, as previously discussed, water temperatures in the Feather River will be compared to several water temperature recommendations. These comparisons will be the bases for determinating the frequency and magnitude of potential water temperature-related effects on pre-spawning adults in the Feather River associated with various operational scenarios. . Potential project effects of water temperatures on pre-spawning adults will be evaluated under different operational scenarios by utilizing the model output from study plan SP-E1.5—Feather River Temperature Model Development, which will generate the required long-term water temperatures. The model produced by the Engineering and Operations Work Group will generate the long-term water temperatures expected under current and/or alternative operational scenarios.

In addition to water temperatures collected in SP-W6, data characterizing the level of dissolved oxygen in the Feather River downstream of Thermalito Afterbay outlet will be collected from SP-W1 and evaluated for compliance with Basin Plan cold water objectives during the warm months of the upmigration period, when dissolved oxygen could drop below recommended values in deep pools. SP-W1 will take vertical profiles of dissolved oxygen during biweekly sampling at the 6 established thermographic stations containing pool habitat from the Thermalito Afterbay outlet to the confluence of the Sacramento River (Verona) from May through October. Water temperature profiles will also be collected at the same time as the dissolved oxygen in these pools through SP-W6. Other water quality parameters (e.g., metals, minerals, and nutrients) will be compared to the requirements for freshwater aquatic life in Task 2 of SP-W1. If exceedances of freshwater aquatic life objectives are observed, then SP-F10 will evaluate the biological impact of the magnitude and extent of the exceedance.

Task 1E— Identify and characterize early up-migrant adult Chinook salmon holding habitat and habitat use patterns

Adult Chinook salmon exhibiting spring-run life-history migrate upstream beginning in March and continuing through July (NMFS 2001). When these adult Chinook salmon enter freshwater, they are sexually immature and their gonads mature during the summer holding period (DWR and USBR 2000). Chinook salmon with spring-run life-history hold in their natal tributaries for up to several months in deep coldwater pools before spawning occurs (NMFS 2001). Holding pools should be sufficiently deep and cool to allow over-summering of pre-spawning adults (DWR and USBR 2000). In the Feather River, most pre-spawning holding adult Chinook salmon typically hold in the upper 3 miles of the Feather River below the Fish Barrier Dam (D. Painter, pers. com. as cited in DWR and USBR 2000), where water temperatures are cooler than water temperatures downstream (DWR and USBR 2000). In the Central Valley, adult Chinook salmon exhibiting spring-run life-history characteristics reportedly begin spawning in mid to late August and may continue through early October, with peak spawning occurring in September (DWR and USBR 2000).

However, little field data exists to corroborate assumptions regarding Chinook salmon migration timing and holding habitat use in the Feather River. Little is known regarding where early-upmigrant Chinook salmon adults hold and whether they spawn successfully. Reasons for this may include a lack of a permanently established upmigration monitoring program, such as a weir or acoustic camera. Additional, there is no geographic segregation of early arriving adult Chinook from later arriving adult Chinook, and as arrival time cannot be distinguished in the field by direct observation, it is not possible to tell whether a holding adult has been holding for a matter of days (fall-run life-history) or a matter of months (spring-run life-history).

Conceptual framework: The water temperature regime associated with the ongoing operation of the Oroville facilities may expose pre-spawning adult Chinook salmon to elevated water temperatures during the holding time period, which may adversely impact reproductive success due to decreased fertilization rates, latent embryonic mortality, and alevin malformations.

The objectives of this task are two-fold. The first objective is to identify and characterize holding pool habitat, and the second objective is to describe the fish holding habitat use and subsequent spawning status.

Identification and characterization of holding pool habitat: Potential holding pools between the Thermalito Diversion Dam and Honcut Creek will be identified using existing DWR habitat maps. Because previous observations suggest that most adult early upmigrant Chinook salmon hold in the three miles of the Feather River immediately downstream from the Fish Barrier Dam (DWR and USBR 2000), the water temperature profile of every pool from the Thermalito Diversion Dam (RM 67) to Mathews Riffle (RM 64) will be determined during the first year of data collection. The Thermalito Diversion Dam was chosen as the upstream extent of holding habitat characterization because of the potential to allow salmonids to hold in the Fish Barrier Pool if the habitat to the Thermalito Diversion Dam is suitable for holding. Water temperatures in the lower portion of the reach between the Thermalito Diversion Dam and the Thermalito Afterbay outlet are generally warmer than the water temperatures in the upper portion of this reach (DWR and USBR 2000). As a result, holding habitat in the lower river portion may be less suitable for adult Chinook. Therefore, water temperature profiles in half of the pools (50%) in this reach will be determined initially. The pools between Mathews Riffle (RM 64) and the Thermalito Afterbay outlet (RM59) will be stratified according to dimensions and a random sample will be taken within each strata. If there are not sufficient differences in pool dimensions to allow for stratification, the selection of pools will be random within this reach. Because water releases from the Thermalito Afterbay cause warmer water temperatures downstream of the Thermalito Afterbay outlet, the most suitable holding habitats are likely upstream of the Thermalito Afterbay outlet (DWR and USBR 2000). Based on water temperature modeling efforts conducted on the Feather River for DWR and USBR's Biological Assessment of the effects of the CVP and SWP on Chinook salmon exhibiting spring-run life-history, it was concluded that for 2000 and 2001, it was unlikely that adult Chinook would use the portion of the Feather River below the Thermalito Afterbay outlet except as a migration corridor to the upper reaches of the river (DWR and USBR 2000). However, fieldwork is necessary to determine whether or not the pools downstream of the Thermalito Afterbay outlet provide water temperatures suitable for holding adult Chinook salmon. Pools will be identified and placed into strata according to pool dimensions as described above, and initially 25% of the pools between the Thermalito Afterbay outlet and Honcut Creek will be sampled according to selection randomly within each strata. The same pools would be sampled each month throughout the first field season.

After the first year of study, results will be summarized and evaluated to determine if the level of survey effort should be re-focused. For example, if initial results suggest that water temperatures are suitable in all deep pools upstream of Mathews Riffle throughout the summer, the following field season fewer pools upstream of Mathews Riffle could be sampled and more effort could be focused on investigating pools downstream where temperatures are closer to the temperature thresholds for holding adult Chinook salmon.

Water temperatures will be measured at half-meter intervals in deep pools bi-weekly from March through October, as specified in SP-W6, Task 1A. In addition to characterization of water temperatures, substrate and cover data will be collected during the first water temperature survey of the year. Dominant substrate size will be assessed visually using the Brusven index system currently in use by DWR (see Table 1, Task 3A of SP-F10). Cover data will also be collected during the snorkel surveys using the currently used DWR cover codes (see section 7.0 Coordination and Implementation under SP-G2).

Description of adult Chinook salmon holding habitat use and subsequent spawning status: In order to assess patterns of holding habitat use specifically for adult Chinook salmon which upmigrate in the spring, approximately 30 adult upmigrating salmonids will be captured and tagged to document their habitat utilization. Beginning in April, adult Chinook will be captured by angling above the confluence of the Feather and Yuba Rivers. Angling will occur for 3 weeks over a period of 3 months, with one week of angling occurring in April, one in May, and one in June. Approximately 30 adults will be radio-tagged and tagged with a water temperature sensor and released in the vicinity of their capture. At least 50% of the tagged population will be female, as the percentage of spawned females will serve as the measure of spawning status. Angling and tagging will cease once approximately 30 adults have been tagged. If, by the end of June, 30 adult Chinook salmon have not been tagged, one week of angling will occur in July. Angling will cease after the week of tagging in July regardless of the number of adult Chinook salmon that have been tagged. It is anticipated that the angling and tagging activities described will require take permits.

Fish movements will be monitored using radio telemetry. Specific details of the radio telemetry monitoring systems will be evaluated for applicability to the early adult up-migrant Chinook salmon study and for joint applicability to radio-tagging studies potentially proposed in other fisheries plans. Considering equipment specifications once the range of needs is identified will allow dual use of receivers and data loggers and prevent additional overlapping expenses. A combination of manual tracking and fixed station data logging will be used to assess the location of adult Chinook salmon. Manual tracking will occur once a week each week from the initiation of tagging until completion of the survey. If, after the week of tagging in July (if necessary), the total number of fish tagged is less than 10, monitoring of fish movement by manual tracking will occur once every two weeks for the duration of the survey. Exact placement of fixed station data loggers will be determined following the choice of equipment. Fixed stations will be placed in appropriate locations beginning approximately 3 weeks prior to the initiation of angling and tagging (April). Consideration for choosing locations for fixed station receivers will include areas with representative thermal complexity, locations exhibiting potential holding habitat, and areas with limited access to protect against equipment vandalism. Water temperature data will be logged using archival tags with data storage capabilities. Water temperature data will be downloaded upon retrieval of fish through the carcass survey (see Task 2B). Fish that are not recovered in the carcass survey will be located using manual tracking methods.

Analyses: To fulfill the first objective, the water temperatures used by pre-spawning adult Chinook salmon in the Feather River can be compared with recommended water temperatures for pre-spawning adults, which will be compiled in Task 1D. As discussed in previous tasks, relying on a single water temperature recommendation is not prudent as different types of studies have different inherent assumptions and biases that may cause the recommendation to be skewed. The water temperature recommendations will be compared and summarized. Recommendations will be compared to the water temperature profile data collected in this task (Task 1E) to determine the frequency with which temperature recommendations are exceeded and the magnitude of the exceedance. Observed water depth (from temperature profiles), cover, and substrate will be compared to the recommended holding habitat characteristics which will be summarized in Task 1D.

To fulfill the second objective, movement of early adult Chinook upmigrants will be tracked and analyzed for holding habitat use patterns. Radio data will be used to determine what sections of the river are used for holding, the length of time spent holding in each section of river, and the effect of artificial structures such as the Thermalito Afterbay outlet on upmigration. Thermistor data will be used to determine what temperatures fish use for holding and thermistor data and carcass survey data will be used to determine whether there is a correlation between thermal history and egg retention in adult females. Radiotagging data, thermistor data, and in-river temperature profiles will be used to determine whether there is any correlation between section of river used and water temperature chosen, whether the percentage of spawned early upmigrants differs from the percentage of the entire Chinook population that spawns, and how water temperature use compares to available water temperatures (i.e., do fish use the coolest waters available?).

Data collected from the radiotagging survey will support development of use profiles for early-upmigrant adult Chinook salmon for water temperature, pool depth, substrate, and cover. The use profiles will allow estimation of the factors that are important for early-upmigrant adult choice of holding habitat. This will allow an estimation of the potential effects of continued operations and various operational scenarios that may change water temperature, pool depth, or other variables, and will facilitate development of PM&Es based on use profiles. Additionally, the radiotagging survey will allow correlation of various environmental variables with spawning status to determine the number of successful spawners utilizing particular habitats. With manual tracking, locations of spawning (by riffle) will be obtained. Because superimposition estimates (Task 2B) will be made by riffle, it will be possible to determine whether the riffles most commonly utilized by early-upmigrant adult Chinook salmon experience more or less superimposition than other riffles. This will allow an assessment of the extent that early-upmigrant adult Chinook salmon are disadvantaged by superimposition. Additionally, radiotagging and tracking will allow determination of the reaches of the Feather River and the riffles in the Feather River which are specifically used by early-upmigrant Chinook salmon adults. This data can be compared with carcass survey data (Task 2B) to determine whether the spawning distribution of early-upmigrant Chinook salmon differs from the rest of the Chinook salmon population.

Task 2—Evaluation of project effects on the spawning, incubation and initial rearing period of salmonids in the Feather River

The Oroville facilities affect flows, water temperatures, and supply of gravel that, in turn, affect spawning, incubation and initial rearing of salmonids. Flow is associated with spawning habitat availability. Flow fluctuations may result in redd dewatering, desiccation or scouring and stranding. Reduction in gravel recruitment may affect the amount and distribution of spawning habitat in the Feather River. Water temperatures can directly affect the spawning and incubation periods of salmonids. Egg incubation at low water temperatures may seriously affect survival, especially during the stage from fertilization to early egg development (EPA 1999). High water temperatures during salmonid egg incubation can result in post emergence mortality because of physiological difficulty in completing yolk absorption (Jewet 1970 as cited in DWR 1988). Water temperature fluctuations can result in mortality attributed to yolk coagulation (Johnson and Brice 1953) and delayed effect of embryo damage (Olson and Foster 1955).

Potential project effects on flows, water temperatures and gravel recruitment will be evaluated during the spawning period for steelhead and Chinook salmon. Steelhead peak spawning occurs from December through April. Currently, little is known about the spawning locations of steelhead on the Feather River. Because steelhead do not necessarily die after spawning, documentation of spawning location cannot be definitively achieved through carcass surveys. However, it has been observed that some steelhead spawn in the small secondary channels of the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet, where substrate size is smaller and cover is greater than in the main river, thus providing a suitable area for spawning (DWR 2001). Feather River Chinook salmon may begin spawning as early as mid-August and spawn through December, with peak spawning occurring in the months of October and November. According to the carcass survey performed in the year 2000, 63% of all Chinook salmon spawning upstream of Honcut Creek occurred in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet, and 37% occurred between the Thermalito Afterbay outlet and Gridley Bridge (DWR, unpublished results).

Task 2A—Evaluate spawning and incubation substrate availability and suitability for salmonids in the Feather River

Suitable habitat is required for redd construction, egg incubation, and emergence. For successful redd construction, the spawning female must be able to move gravels to excavate a depression in the bed to create a redd. Spawning females need not move all rocks present, but most of the particles present must be moveable or the redd cannot be excavated. In order for eggs to survive the incubation period, gravel must be sufficiently free of fine sediment that the flow of water through the gravel brings adequate dissolved oxygen to the eggs and carries off metabolic wastes. Emergence requires that hatched alevins living in the intragravel environment pass through connected pore space in the gravel, and therefore fine sediments must not block intragravel pore space. Suitability of gravel will, in part, determine the ability of salmonids to construct reds, survive incubation, and emerge from the intragravel environment. Because gravel requirements for redd construction, incubation, and emergence vary, the requirement for each species should be examined separately (Kondolf 2000).

Conceptual Framework. The operation of Oroville facilities may affect the distribution and quality of spawning gravel in the current Feather River spawning grounds of salmonids.

Spawning Gravel Sampling. In order to assess the suitability of available gravel for spawning and initial rearing habitat, gravel size and distribution must be determined. To maximize resources and provide cost-effective data collection, gravel sampling and size distribution data will be obtained from SP-G2—Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam. SP-G2 specifies that gravel will be sampled and sieved from the upstream end of salmon spawning riffles. Representative areas at the head of riffles will be analyzed using bulk gravel sampling and surface sampling techniques to determine the surface substrate quality of salmon spawning gravel. Gradation curves for each riffle will be prepared and compared to similar investigations done in 1982, and 1997. In addition, Wolman surface grid sampling will be performed at each sieve site and a mathematical relation between the two sampling methods will be developed and compared. SP-G2 also will identify, classify, and measure the velocity, width, depth, and length of spawning riffles. Gradation curves produced in SP-G2 will allow an assessment of the quality of spawning gravel for egg incubation and emergence (see Analyses). The sieving of surface and bulk gravel samples will facilitate evaluation of sediment armoring.

SP-G2 will also assess the permeability of the substrate, intragravel water temperature, and intragravel dissolved oxygen. Substrate permeability at each spawning riffle will be measured directly in the field using a piezometer (Barnard and McBain 1994, Vyverberg, et al. 1997). The piezometer will be driven into the gravel by hand. The rate of flow into the piezometer will be measured by maintaining a 2.5 cm pressure head and collecting the water flowing into the piezometer in a 1L graduated cylinder. The volume per unit time (inflow rate) will be recorded and standardized to a temperature of 10ºC. Permeability will be estimated from the empirical curve describing the relationship between standpipe inflow and permeability (Barnard and McBain 1994) and will be corrected for viscosity (Barnard and MacBain 1994, Vyverberg, et al. 1997). Intragravel temperature will be measured by evacuating surface water from the piezometer, allowing intragravel water to fill the piezometer, inserting a thermograph probe into the piezometer and reading the thermograph following equilibration (Vyverberg 1997). Intragravel dissolved oxygen concentrations will be measured by a similar method. Following evacuation of surface water from the piezometer, a dissolved oxygen probe will be inserted into the standpipe to measure the dissolved oxygen concentration (Barnard and McBain 1994).

Analyses. In order to determine whether the framework gravels present in the river bed are too large for female spawning salmonids to move when excavating a redd, the d_{50} (median diameter of spawning gravels) will be compared to those reported for the species elsewhere and with the maximum movable size calculated by Kondolf (Kondolf 2000). Kondolf suggests that spawning fish can move gravels with a median diameter up to approximately 10% of their body length. Median diameter of spawning gravel will be determined from gradation curves generated in SP-G2. Body length of spawning Chinook salmon adults will be obtained from carcass surveys conducted in Task 2B of this study plan and body length of adult steelhead will be obtained from the Feather River hatchery. Data will be reduced to determine the percentage spawning gravel suitable for redd excavation for each salmonid species at each riffle analyzed.

Size of the gravel is not the only factor influencing suitability of gravel for redd excavation. In some channels, gravels may be compacted or cemented, rendering otherwise suitably sized gravels unsuitable. Spawning gravel use will be compared to permeability and substrate armoring to determine if either permeability or substrate armoring shows a relationship to gravel use. The permeability at each riffle will be compared to the number of fish spawning at each riffle (from carcass survey, Task 2B) to determine if the number of spawners varies significantly as a function of permeability using a statistical comparison such as a two-factor ANOVA. An evaluation of the armoring of sediments will be accomplished in consort with substrate size determination occurring in SP-G2. When surface and bulk gravel samples are sieved for determination of substrate size, the ratio of the median grain size of the armored layer (d_{50A}) to the median grain sized of the subsurface particles (d_{50SUB}) will be calculated and defined as the armoring index (Vyverberg, et al. 1997). This ratio serves as an estimate of the amount of armoring that has occurred at each riffle. An index of 1 would indicate an absence of armoring, whereas indices of greater than 1 would indicate a higher degrees of armoring. Armoring indices will be compared to those found in other Central Valley rivers (Vyverberg, et al. 1997) and will be compared to armoring index reported for other gravel bed streams (Parker 1982). Estimates of number of fish using each spawning riffle will be obtained during the carcass survey. Armoring at each riffle will be compared to the number of fish spawning at each riffle to determine if the number of spawners varies significantly as a function of armoring using a two-factor ANOVA. Additionally, intragravel water temperature and intragravel dissolved oxygen will be compared to number of fish spawning at each riffle to determine the number of spawners varies significantly as a function of intragravel water temperature or dissolved oxygen.

In order to determine whether fine sediment content is excessive for incubation, it is necessary to determine whether the amount of sediment finer than 1 mm is so great that gravel permeability and resultant intragravel flow are negatively affected. The percentage finer than 1 mm will be determined from the gradation curves adjusted downward by 23%, as recommended by Kondolf (Kondolf 2000). The downward adjustment factors in the probable cleaning effect associated with redd construction before analysis of sediment content. The values resulting from the downward adjustment will be compared to values reported elsewhere. The relationship between the percentage fines and incubation will be investigated using a variety of previously established criteria. An example of the criteria that may be used in this analysis includes the criteria presented by Kondolf which includes a table summarizing various studies of steelhead and Chinook redd sediment content values for maximum percentage grains finer than 1.0 mm corresponding to 50% emergence of salmonids (Kondolf 2000). Data will be reduced to determine if the quantity of fine grains less than 1.0 mm predicts more or less than 50% emergence. Other criteria may include gravel sizes that predict various percentages of egg survival, such as those detailed by Reiser and White (1988).

The relationship between the percentage fines and emergence will also be investigated using a variety of previously established criteria. One example of criteria that may be used includes the criteria developed by Kondolf (2000) described here. In order to determine whether fine sediment content is excessive, potentially blocking the upward migration of fry (emergence), the percentage finer than 3,6, or 10 mm will be compared with values reported from redds elsewhere and with standards drawn from laboratory and field studies of incubation and emergence (Kondolf 2000). However, the upper limits of fine sediments affecting emergence (percentages less than 3-10 mm) are more difficult to select, and show considerable variability. As with the percentage of sediment less than 1 mm, the percentages less than 3, 6, or 10 mm should be adjusted downward to reflect the probable cleaning effect of redd construction, but the effects of redd building on these sizes are more variable than they are upon the percentage fine than 1 mm. A downward adjustment of 42% is suggested (Kondolf 2000), although caution is advised due to large variability in data used to generate the adjustment data. Other criteria for emergence may include those that correlate percentage sand to percentage emergence.

Task 2B—Evaluate the timing, magnitude and frequency of flows on spawning distribution

Introduction. All of the in-river salmonid spawning activity occurs downstream of the fish barrier dam. Most of the Chinook salmon spawning activity is concentrated from the fish barrier dam down to the Thermalito Afterbay Outlet, where the median of August 15 - January 1 daily flows was 862 cfs[1] in 1995-1997, and minimum daily flow was 515 cfs. An estimated 37% of Chinook salmon spawning occurs below the Thermalito Afterbay Outlet down to Honcut Creek, where median daily flow for the same months and years was 2,400 cfs[2], and the minimum was 1,690 cfs. Almost all of the steelhead spawning activity appears to be concentrated from the fish barrier dam down to the Thermalito Afterbay Outlet, where the median of December 15 - April 30 mean daily flows was 557 cfs, and the minimum was 510 cfs.

Chinook salmon spawning escapement abundance has been estimated by DFG since 1955, mostly though carcass surveys. The series of abundance estimates presents some gaps prior to 1970. Since 2000, DWR has taken the lead in the conduct of carcass surveys. Carcass surveys do not differentiate between fall-run and Chinook salmon exhibiting spring-run life history characteristics. From 1995 through 1999, DWR performed aerial surveys to quantify Chinook salmon redds in the reach of the Feather River extending from the Fish Barrier Dam to the confluence with Honcut Creek from late October through November. At present, no estimates of spawning escapement abundance or redd counts exist for steelhead in the Feather River.

The evaluation of the existing aerial photographs obtained by DWR from 1995 to 1999 for the purpose of redd detection and enumeration elicited a series of problems that curtail the effectiveness of aerial redd surveys. The list of problems includes, but is not limited to: 1) inability to differentiate redds in situations of intensive utilization of the spawning areas, 2) subjective interpretation, repeatability and mylar registration problems with the redd evaluation process, and 3) aerial photography-related problems such as those caused by sun angle, look angle, lighting condition, wind conditions (e.g., wind causing ripples that reduce substrate visibility), fog and rain obscuration, airplane availability and cloud and tree shadows. Redd detection conducted with aerial photography has been generally restricted to small creeks or streams without intensive spawning and to areas with good visibility conditions, often when other more quantitatively reliable methods, such as carcass surveys are not available. Fortunately in the case of the Feather River, where past aerial redd surveys proved to be unreliable, the on-going intensive carcass surveys can provide better quality information on salmonid spawning intensity, distribution and characteristics (e.g., proportion of unspawned females, degree of redd superimposition, proportions of hatchery and wild in-river spawners, etc) to correlate with Feather River flow characteristics, and probably identify and assess flow-related effects on salmonid spawning. The adverb "probably" is used here to warn against a series of other factors (e.g., hatchery effluent, fidelity of hatchery fish to the hatchery, temperatures, gravel quality, etc) that may also affect salmonid spawning and acting as confounding variables limit the possibility of assessing flow-related effects on salmonid spawning.

This study proposes to collect, assimilate and analyze spawning, redd and carcass data to:

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1 Median and minimum were calculated using daily flows as reported by the USGS gage station at Oroville on the Feather River (USGS 11406999) from August 15, 1995 to January 1, 1998.

2 Median and minimum were calculated using daily flows as reported by the USGS gage station at Gridley (USGS 11407150) from January 1, 1995 to January 1, 1998.

- Assess potential relationships between the number of Feather River salmonid spawners and flow;
- Assess potential relationships between the spawning timing of Feather River salmonids and flow;
- Appraise the relationship between the geographical distribution of Feather River salmonid spawners and flow;
- Describe the temporal and geographical distributions of hatchery and wild adult salmonid spawners;
- Evaluate the amount of redd superimposition by area and time of the year (e.g., month or week) to infer the potential impact of crowding to Chinook salmon exhibiting spring-run life history;
- Describe the temporal and geographical distributions of spawned female adult salmonids and evaluate their potential relationships to Feather River flows; and
- Obtain empirical evidence suitable to validate PHABSIM outputs.

Flow fluctuations during the spawning period will be evaluated under Task 2D— *Evaluate flow fluctuation-related effects on redd dewatering*, through redd dewatering surveys. Five activities have been envisioned for Task 2B:

1. Evaluate available past data on salmonid spawning;
2. Review and evaluate methods to measure steelhead spawning;
3. Perform carcass survey for Chinook salmon;
4. Evaluate Chinook salmon redd superimposition; and
5. Perform redd surveys for steelhead.

Conceptual Framework. The flow regime associated with the ongoing operation of Oroville facilities may affect the spawning activity of Feather River salmonids.

Evaluation of Existing Data. The review and evaluation of existing salmonid spawning data will: (1) evaluate data quality and consistency of past efforts to evaluate Chinook salmon spawning timing in the Feather River; (2) compare available consistent series of data on Chinook salmon spawning with available corresponding series of flow records for the Feather River Fish Barrier Dam down to the Thermalito Afterbay Outlet and Thermalito Afterbay Outlet down to Honcut Creek; (3) provide insight on potential changes to current carcass survey protocol and experimental design; and (4) develop and test initial working hypotheses on the effects of the timing, magnitude and frequency of flows on spawning anadromous salmonids.

Flow data for the Feather River Fish Barrier Dam down to the Thermalito Afterbay Outlet and Thermalito Afterbay Outlet down to Honcut Creek that will be used for the development and testing of initial working hypotheses on the effects of the timing, magnitude and frequency of flows on spawning anadromous salmonids will be collected and evaluated. The data review will involve contact with USGS and the California Data Exchange Center (CDEC) and an evaluation of the quality of the available records. Meetings with the Engineering and Operations Work Group will be held at this stage to ensure that SP-F10 will be using the same flow records used by the Engineering and Operations Work Group in their modeling effort (e.g., SP-E.1.6 Feather River Temperature Model Development), as well as to avoid the duplication of effort on gathering and processing available flow records. Prior to evaluating potential flow effects on the spawning of Feather River salmonids, the available time series of flow records will be inspected for consistency, data gaps and recording errors. In selecting adequate time series of flow records for the analyses (see below), the locations of the recording gage stations, the period of continuous record, and synchronicity of the flow records with the available salmonid spawning data will be considered.

Review and Evaluation of Study Methodology on Steelhead Spawning. The review and evaluation of methods currently used to measure steelhead spawning will be based on published scientific articles and reports. The methods applied to measure spawning of steelhead in other river basins will be compared to achieve quantifiable and potentially unbiased measures. The methods will then be categorized in terms of their applicability to the Feather River conditions. The objective of this review and evaluation is to identify opportunities for improvement in a method to quantify steelhead spawning in the Feather River. As mentioned earlier, currently no estimates of spawning escapement abundance or redd counts for Feather River steelhead are available. Such lack of information limits the evaluation of flow effects on steelhead.

Chinook Salmon Carcass Survey. An additional carcass survey is proposed for the 2002-2003 spawning season. The survey will be conducted in both the Feather River reaches extending from the Fish Barrier Dam to the Thermalito Afterbay Outlet, and from the Thermalito Afterbay Outlet to the confluence with Honcut Creek, from mid-August through late-December. The survey period was selected to ensure that both spring-run and fall-run Chinook salmon are included in the survey.

The objectives of the survey include: (1) the assessment of the Chinook salmon population naturally spawning in the Feather River in 2002, to enlarge the series of Chinook spawning escapement abundance estimates, started in 1955, that will allow the testing of hypotheses on flow effects on spawning, (2) assessment of the contribution of hatchery-reared Chinook salmon and salmon from other rivers to the population of Chinook salmon naturally spawning in the Feather River, (3) evaluation of spawning timing, (4) calculation of the annual and weekly sex ratio of the population of Chinook salmon naturally spawning in the lower Feather River, (5) calculation of the annual and weekly ratio of spawned females in the population of Chinook salmon naturally spawning in the lower Feather River, and (6) calculation of annual and weekly pre-spawning mortality. Details on the proposed carcass survey protocol are provided below.

Each survey week a crew of six to nine staff members will survey the study area from two to three boats, searching for salmon carcasses. In order to manage data, document spawning distribution and achieve accurate results, the study area will be divided into approximately 40 sections, each section approximating a single riffle/pool sequence. Each week and in each section, all fresh carcasses will be counted and tagged with an individually numbered tag inserted in the lower jaw. Fresh carcasses are carcasses with either one clear eye or pink gills. Carcasses that do not satisfy these conditions are non-fresh or decayed. The individually numbered tags will allow identification of tagging week and site (i.e., section). If on a particular sampling date no fresh carcasses are found, the sampling date and site, and a count of “zero” will be recorded. All observed non-fresh carcasses will be counted but will not be tagged. They will be chopped to avoid their counting in subsequent sampling weeks. The number of decayed carcasses counted, and the date and site of the observation will be recorded. Chopped carcasses will be returned to the river.

The fork length (to the nearest cm) and sex of all fresh carcasses tagged weekly will be recorded. All fresh female carcasses will be visually inspected for spawning status and classified into three categories: not spawned (e.g., nearly fully ovaries), partially spawned (e.g., more than 50% egg retention) and fully spawned (e.g., few eggs remaining).

Each sampling week all observed carcasses will be inspected for presence of the individually numbered tags released in previous sampling weeks. If a tag is found, the carcass will be chopped and returned to the river. The tag number, date, and site of the recovery will be recorded. The amount of carcass drift of these recovered carcasses will be evaluated to determine if any carcasses move from the tagging origin riffle to a lower spawning riffle location. If carcasses move from one riffle-pool sequence to another spawning riffle, the relative proportion of tagged vs. spawning riffle drifted carcasses will be used to adjust carcass estimates for each spawning riffle. Besides inspecting for the presence of the survey individually numbered tags, all observed carcasses with clipped adipose fins will be counted, and the numbers, date and site will be recorded. The head from adipose-clipped carcasses will be removed and retained in individually labeled plastic bags for later detection, removal and decoding of coded-wire tags (CWT). Plastic-bag labels will indicate date, site of recovery and fork length of carcass. Similarly, for all carcasses with radio tags (see Task 1E) that are recovered, the tag identification, date, and site of the recovery will be recorded in a separate database.

Additionally, each sampling week water temperature and turbidity will be measured using thermometers and Secchi-disc. Temperature (ºF) and Secchi-disc depth will be recorded at each sampling section at the start and end of the sampling day**.** Temperature and turbidity measurements will provide additional factors that can be analyzed to evaluate their effects on spawning activity and abundance measurement estimates. High turbidity reduces chances of spotting carcasses, which may lead to an undercount of carcasses and consequently to biased spawning escapement estimates.

After each sampling week, data-entry personnel will check data for errors. Survey data will be stored in individual electronic files. Files will contain all raw information and will be in ASCII comma-separated variable format, or other easily transferable file format. At the end of the survey, the number of decayed carcasses observed, the numbers of female and male fresh carcasses released and recovered will be tallied by week (identified by a starting and ending date) to estimate spawning escapement abundance.

The Schaefer mark-recovery method (Schaefer, 1951) as modified by Taylor (1974) will be applied to the tagged and recovered fresh carcasses and total number of carcasses counted (both fresh and decayed) to produce abundance estimates. Abundance will be estimated for the entire survey and for each reach and recovery week. Since not every salmonid carcass on the river can be counted directly, the Schaefer mark-recapture method allows an estimate of sampling efficiency. The number of carcasses directly observed can then be statistically expanded using the weekly sampling efficiency to gain an estimate of the total population. The new Schaefer abundance estimate for the entire survey will be added to the series of available abundance estimates for testing of hypotheses concerning the effects of flows (as well as other factors such as temperature and turbidity) on Feather River Chinook spawning. The temporal distributions of observed carcasses and their lengths will be evaluated to identify potential ways to separate spring-run Chinook carcasses from fall-run Chinook salmon carcasses through temporal distribution of spawning activity or other appropriate technique.

The number of observed male and female fresh carcasses will be tallied per week to evaluate sex-ratio changes through the spawning season and among spawning seasons. The number of unspawned and spawned females will be tallied per week to evaluate changes in the weekly proportion of unspawned females through the spawning season. The proportion of unspawned females for the whole survey period has been used as a measure of pre-spawning mortality. The weekly and season-long proportions of unspawned females can be regarded as measures of spawning and will be used to test hypotheses on the effects of flows on percent spawning.

Redd Superimposition. The superimposition of redds may result in poor egg to fry survival rates due to disruption of previously constructed redds (Litchfield and Willete, 2002). Destruction of the eggs and increased egg and alevin mortality are often the outcome of high levels of redd superimposition. High levels of redd superimposition may be a symptom of crowded spawning conditions resulting from an excessive number of spawning salmon for the suitable spawning habitat under a particular flow rate. Moreover, redd superimposition may be a factor disproportionately affecting early spawners and thus potentially affect the spawning success of Chinook salmon exhibiting spring-run life history.

Previous field observations of spawning suggested that redd superimposition might be a major problem in the Feather River (Sommer et al. 2001). Sommer et al. (2001), using a superimposition index (SI), estimated that in 1995 redd superimposition in the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet ($SI_{LFC} = 1.57$) was greater than the redd superimposition in the reach extending from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek ($SI_{LFC} = 0.47$). The superimposition index was calculated as:

$$SI = \frac{\left(\text{Escapement Estimate} \times 0.5\right)}{\left(\text{Spawning Area in ft}^2 / 55\ \text{ft}^2\right)}$$

The spawning area was calculated from 1995 aerial surveys, and the escapement estimate came from the 1995 carcass survey. The 0.5 constant assumed an equal sex proportion, and the 55 ft^2 constant corresponds to the average surface area of an average size fall-run Chinook salmon redd. Although the SI suggests higher superimposition in the fish barrier dam down to the Thermalito Afterbay Outlet, SI should not be considered actual measure of superimposition rates (Sommer et al. 2001).

Because of the high spawning concentrations and the resulting level of redd superimposition, particularly in the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet, and other factors identified in the introduction to Task 2B, it is not possible to readily distinguish individual redds based on aerial photography. This study will use the carcass survey data instead of the aerial redd surveys to estimate incidence of redd superimposition by reach and time of the year (e.g., month or week) for Chinook salmon. Redd superimposition will be calculated using a superimposition index similar to the SI used by Sommer et al. (2001).

Data collected during the carcass surveys will be used to estimate of the total number of adult Chinook salmon and the proportion of spawned females by month or week and by survey area. These estimates will be the numerators of the superimposition index. Initially, two areas will be considered: the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and the reach extending from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek. However, the potential for a finer geographical scale will also be studied. The sizes of each riffle section where carcasses have been observed in the course of each sampling week will be calculated by estimation of spawning area from aerial photographs or by real-time kinematic (RTK) GPS survey of the spawning area boundaries and will be corrected for any potential carcass drift. The calculated sizes will be added to produce estimates of weekly or monthly spawning areas (denominator of the SI formula) in the reaches extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek.

Because 55 ft^2 used in earlier SI calculations (Sommer et al. 2001) as the average size of appears to be a conservative estimate, which would tend to over-estimate the amount of superimposition, a literature search on average redd size estimates will be conducted. Redd-size data collected during previous carcass surveys will be analyzed and used to calculate an average redd size. It is anticipated that previous redd size measurements will be sufficient for calculation of average redd size, but if sufficient information is not available, at least 50 newly built redds will be sampled for size (maximum width and length in feet) during the current carcass surveys. The redd-size measurements will be spread along the survey season. The selection of redds for size measurement will be as random as possible although limited by site accessibility and potential for disruption of salmonid spawning activity. Besides the redd dimensions (i.e., maximum width and length), the location and date of the measurement will be recorded for each new redd-size measurement. The newly acquired redd-size measurements will be compared to the 55 ft^2 used in earlier SI calculations and the information obtained from literature search to obtain more precise superimposition indices. If redd size is found to be different from the 55 ft^2 used in earlier SI calculations, the SI will be recalculated using the new redd size information in order to provide results compatible the data collected for this plan.

The incidence of redd superimposition by reach and time of the year (e.g., month or week) for Chinook salmon as measured by the redd superimposition indices will be used to evaluate any potential relationship of redd superimposition and flow. The potential effects of other factors such as intragravel permeability, armoring, and other physical substrate variables obtained through study plan SP-G2 will also be analyzed.

Steelhead Spawning Sites. Steelhead typically spawn in shallow areas of six to 24 inches deep, with water temperatures reportedly ranging from 39°F to 52°F (McEwan and Jackson 1996; Myrick 1998). Spawning occurs mainly in gravel substrate where females deposit an average of 4,000 eggs. The eggs incubate in the gravel for approximately four weeks. Fry emerge from the gravel about four to six weeks after hatching. The newly emerged fry move to the shallow, protected areas associated with the stream margin. They soon move to other areas of the stream riffles, pools or deeper runs to establish feeding locations.

For most rivers and streams of the Sacramento River basin, detailed information on steelhead spawning sites and abundance is poor because steelhead life-history traits have hampered steelhead monitoring and research (McEwan 2001). Adults tend to migrate during high flow periods, making them difficult to observe. Carcass surveys, a reliable method to estimate Chinook salmon spawning escapement, is not applicable to steelhead because many adults survive spawning and most adults that do not survive do not die on the spawning grounds. In addition, although steelhead redds can be discerned from salmon redds, they are hard to observe because steelhead spawn at higher flows than do Chinook salmon.

In the Feather River, steelhead peak spawning occurs from December through April. As with other Central Valley rivers, there is no information on Feather River steelhead spawning sites and abundance coming from carcass or redd surveys. However, some information on the distribution of spawning steelhead in the Feather River can be inferred from observations collected during the snorkel surveys performed by DWR from March through August in 1999, 2000 and 2001. From 1999 to 2001, almost all of the steelhead spawning activity appears to have been concentrated between the Fish Barrier Dam and the Thermalito Afterbay Outlet, because

91%, 77% and 84% of all the young-of-the-year (i.e., juveniles with fork lengths smaller than 100 mm) steelhead observations during the snorkel surveys of 1999, 2000 and 2001, occurred a mile downstream of the Fish Barrier Dam, and only 1% of the young-of-the-year (YOY) were observed downstream of the Thermalito Afterbay Outlet.

Although our current knowledge on steelhead-spawning distribution suggests that most of the steelhead spawning activity appears to be concentrated between the Fish Barrier Dam and the Thermalito Afterbay Outlet, where flows remain relatively constant (e.g., the 95% confidence limits of the mean daily flows measured at the USGS gage station at Oroville on the Feather River (USGS 11406999) from December 15, 1999 to April 20, 2000 were 503 and 555 cfs), and consequently little negative flow-related effects on steelhead spawning might be expected, our current lack of detailed information on steelhead spawning locations and abundance curtails any attempt to test for the effects of flow or other environmental factors. Hence, our current priorities are: 1) to obtain detailed information on the distribution of spawning steelhead in the Feather River, 2) to evaluate different alternatives to provide measures for the distribution and abundance of potential steelhead spawning in the Feather River, and 3) to provide the bases for the development of a plan to monitor the abundance and distribution of steelhead spawning in the Feather River.

The approach chosen to achieve the three goals mentioned above consists of five activities: 1) evaluation of the distribution of fry-sized YOY steelhead observed in the 1998-2000 snorkel surveys, 2) adult steelhead abundance boat survey, 3) extended snorkel surveys and 4) steelhead redd ground survey.

The observations of YOY steelhead obtained during the 1998-2000 snorkel surveys will be reanalyzed to provide further insight on the temporal and geographic distribution and abundance of the smallest, fry-sized YOY steelhead. YOY steelhead counts and counts per minute classified into 10-mm size-classes will be analyzed by month, river reach, habitat type, water depth and distance from the channel edge to gather information on the temporal and geographic distribution and abundance of the smallest YOY steelhead. Because fry normally emerge from the gravel about four to six weeks after hatching moving to the shallow, protected areas close to their hatching grounds, it is expected that the temporal and geographic distribution and abundance of the smallest YOY steelhead coming from this evaluation will provide clues on the most likely location of steelhead spawning sites. The sites thus selected will be assigned a higher level of sampling effort during the extended snorkel surveys and redd ground survey described in paragraphs below.

An adult steelhead abundance boat survey will be performed weekly from mid December through April. Each week, a field crews will float the Feather River from the confluence with the Yuba River to the Fish Barrier Dam in search of adult steelhead. Observations of adult steelhead will be made from both sides of the viewing platform. The date, time, location and number of observed adult steelhead, and number observed spawning will be recorded to provide weekly counts and distribution of adult fish during the peak months of steelhead spawning activity in the Feather River. Additionally, any observed Chinook salmon spawning will be documented, although Chinook salmon adults are not expected to spawn during this time period. Chinook salmon spawning observations will be recorded and analyzed as described for the steelhead spawning observations. In addition to the boat survey to determine distribution of spawning steelhead, anglers will be asked to report information regarding observations of the number and location of steelhead observed spawning. Any appropriate information collected through the angler survey conducted in SP-R13 will be used to estimate adult steelhead abundance and distribution of spawning adults.

The snorkel surveys will be extended to cover the months of peak steelhead spawning activity (mid December through April). The nine fixed stations of the intermediate-scale surveys (six in the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet, and three in the lower reach downstream of the Thermalito Afterbay River Outlet) will also be surveyed from December through February following the sampling procedure described in the "Ongoing field studies" section of Task 3A. Besides the nine fixed stations, a maximum of 10 additional stations will be sampled each month from December through April. The location of these additional stations will be based on the outcome of the evaluation of the distribution of fry-sized YOY steelhead observed in the 1998-2000 snorkel surveys described in earlier paragraphs. Newly collected YOY steelhead observations and counts per minute will be classified into 10-mm size-classes and analyzed by month, river reach, habitat type, water depth and distance from the channel edge to gather information on the temporal and geographic distribution and abundance of the smallest YOY steelhead.

A redd ground survey for steelhead will take place from mid December through April. The redd ground survey will be conducted weekly by wading or boat observation, with field crews identifying and counting individual redds within 100 ft of 40 transects (one for each section sampled by the carcass surveys). Additional transects will be added in the areas which the evaluation of the 1998-2000 snorkel surveys showed as holding large concentrations of fry-sized YOY steelhead. Each steelhead redd newly identified will be counted, and its position and observation date will be recorded. If site accessibility allows it, and if the potential for disruption of steelhead spawning activity is minimal, the size (i.e., maximum width and length) of the newly identified redd will be measured and recorded. The data collected during the redd ground survey will provide weekly distributions of redd counts during the peak months of steelhead spawning activity in the Feather River.

The data gathered by the adult steelhead abundance boat survey, extended snorkel survey, and redd ground survey will be independently analyzed to define potential steelhead spawning areas, and provide measures of spawning abundance or activity. Then, these independent results will be compared. It is expected that the correspondence among the potential steelhead spawning areas identified through each method will provide a more reliable demarcation of the steelhead spawning grounds. Moreover, the comparison of the independently obtained measures of spawning abundance may provide insight on the best ways to quantify the spawning activity of Feather River steelhead.

Analyses. The potential effects of Feather River flows on salmonid spawning from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek will be evaluated by correlating corresponding series of monthly or weekly flows and measures of anadromous salmonid spawning for both river sections. Potential empirical relationships will be identified and described as simple linear or nonlinear functions of the flow variable. Under this approach, potential effects would be suggested when low values of spawning show a significant relation to low flow values. Alternatively, flow effects could be shown by comparing measures of anadromous salmonid spawning obtained under periods of low and high flows through an ANOVA procedure. Under this second approach, potential effects would be indicated when the two series of spawning activity measures are significantly different.

The flow-effect hypothesis may take different guises depending upon the variable used to represent anadromous salmonid spawning. For instance, low flows may be associated with low spawning escapement abundance estimates or low carcass counts. Alternatively, low numbers of spawned female salmon, high redd superimposition or high pre-spawning mortality might be related to low flows. In general, the credibility of a hypothesis on flow effects on anadromous salmonid spawning will increase as more alternative measures of spawning (e.g., spawning escapement, pre-spawning mortality, redd superimposition) are shown to be related to flows. The effects of other factors (e.g., hatchery effluent, fidelity of hatchery fish to the hatchery, temperatures, gravel quality, etc) that may also affect salmonid spawning and confound the assessment of flow-related effects on salmonid spawning will also be investigated, contingent on the quality and extent of the available information.

One particular objective of Task 2B is to describe the temporal and geographical distributions of hatchery and wild adult salmonid spawners. Because, at least since 1999, the study area surveyed during the carcass surveys has been divided into approximately 40 sections, each section approximating a single riffle/pool sequence and the location of the carcass observation recorded, there is fine-scale data on the geographic distribution, both longitudinal (e.g., by river mile) as well as lateral (e.g., right, middle and left of channel). It is expected that this geographical information and the records on recovered CWTs and adipose-clipped carcasses will allow a better description of the temporal and geographical distributions of hatchery and wild Chinook salmon spawners. The relative proportion of adipose-fin clipped Chinook salmon carcasses recovered in the carcass survey will serve as an estimate of the distribution of hatchery spawners. An evaluation of the temporal and geographical distributions of hatchery and wild Chinook salmon spawners may provide answers to questions such as whether the distribution of hatchery fish is responsible for the larger abundance of Chinook salmon spawners reported for the Feather River between the Fish Barrier Dam and the Thermalito Afterbay River Outlet. Comparisons of the proportion of coded wire tagged or adipose-clipped carcasses in both Feather River sections may contribute answers to questions on potential effect of the distribution of hatchery Chinook salmon spawners on the general distribution of Chinook salmon in-river spawners.

The incidence of redd superimposition by reach and time of the year (e.g., month or week) for Chinook salmon as measured by the redd superimposition indices (see above) will be used to evaluate any potential relationship of redd superimposition and flow, as well as potential effects of other factors such as intragravel permeability, armoring, and other physical substrate variables obtained through study plan SP-G2 will also be analyzed. Moreover, the evaluation of the amount of redd superimposition by area and time of the year may help to infer the potential impact of crowding to Chinook salmon exhibiting spring-run life history or earlier Chinook salmon spawners.

A final objective of Task 2B is to obtain empirical evidence suitable to validate PHABSIM outputs generated in SP-F16. It is expected that the comparison of any empirical relationship obtained by regressing the estimates of spawning Chinook salmon abundance against flow measures for the Feather River with PHABSIM outputs that predicts the amount of spawning habitat at different flow levels will provide the validation of PHABSIM outputs. This comparison will be conducted for the Feather River between the Fish Barrier Dam and the Thermalito Afterbay River Outlet, and for the Feather River between the Thermalito Afterbay River Outlet and the confluence with Honcut Creek.

Task 2C—Evaluate the timing, magnitude and frequency of water temperatures and their effects on the distribution of salmonid spawning and on egg and alevin survival

Steelhead typically spawn in shallow areas of six to 24 inches deep, with water temperatures reportedly ranging from 39°F to 52°F (McEwan and Jackson 1996; Myrick 1998). Spawning occurs mainly in gravel substrate where females deposit an average of 4,000 eggs. The eggs incubate in the gravel for approximately four weeks, remaining in the gravel for another four to six weeks after hatching. Water temperatures above 56°F may induce egg mortality (DWR and USBR 2000).

Reported Chinook salmon optimal spawning occurs in water temperatures ranging from 53°F to 57°F (Boles 1988). Spawning occurs mainly in gravel riffles, where females, depending on size, lay 2,000 to 14,000 eggs (Moyle 1976). The eggs incubate in the gravel for 60 to 90 days, depending on water temperature (DWR 2001). Moyle (1976) reported that maximum egg survival is dependent on water temperatures less than 58°F.

Task 2 C attempts to address whether water temperature in the spawning grounds is related to the observed temporal and spatial distribution of Feather River salmonid spawning; how often Feather River water temperatures during the months of salmonid spawning and egg incubation are above or below the literature prescribed temperatures for salmonid spawning, egg incubation and alevin survival; and what would be the expected water-temperature impacts to Chinook salmon early life stages, under current operation conditions. Accordingly, the task has three objectives:

1. Assess the relationship between Feather River water temperatures and the spatial and temporal distribution of Chinook salmon spawning;
2. Appraise general potential water-temperature effects on egg and alevin survival of Feather River salmonids; and
3. Model water-temperature impacts to early life stages of Feather River Chinook salmon.

To accomplish these objectives a literature review of studies on water temperature-related effects on salmonid spawning, egg and alevin survival will be performed, accompanied by a review of available site-specific water-temperature records including intragravel temperature. Moreover, the detailed records of recent Chinook salmon carcass surveys will be processed to provide site-specific weekly estimates of numbers of Chinook salmon carcasses and numbers of spawned female Chinook salmon. Finally, available Chinook salmon mortality models will be reviewed and their applicability to estimate potential Feather River water-temperature impacts on Chinook salmon early life stages will be evaluated.

Conceptual Framework. The water temperature regime associated with the ongoing operation of Oroville facilities may affect the distribution of Feather River salmonid spawning, and egg and alevin survival.

Review of Water Temperature Effects on Salmonid Spawning, Eggs and Alevins. Information obtained from the literature review of studies based on both laboratory and field experiments, as well as reported observations on water temperature-related effects and empirical relationships between water temperature and fish biological performance (e.g., egg retention percentage, incubation period, egg and alevin survival, etc) that will be conducted under Task 1D, will be compiled to provide a thorough, fully documented list of water temperature recommendations. Several investigators have published reviews of water temperature effects on salmonid egg retention and egg and alevins survival, and these published reviews will be utilized to integrate complied information from many types of experiments and field observations. As previously discussed, a comparison with different water temperature recommendations is necessary to avoid utilizing a water temperature recommendation that may be biased because of previously discussed problems with laboratory studies. Moreover, although water temperature recommendations for spawning and incubation may be based on field studies, this field data may not be free from bias because observations that fish inhabit streams with high maximum water temperatures measured in mid-stream may lead to the faulty conclusion that a species tolerates water temperatures of this magnitude unless the water temperature in the immediate environment of the fish is measured.

Even local measures can be misleading, unless a daily time budget for individuals and the population in different water temperature zones or unless internal body temperatures are tracked in relation to ambient temperatures (e.g., Spigarelli et al. 1983; Berman and Quinn 1991). Selection of water temperatures within a thermal gradient cannot be averaged simply based upon time spent in each thermal environment, because the rate of equilibrium of a fish's internal body temperature to a warmwater bath was faster than equilibrium to a cold water bath (Berman and Quinn 1991). Also, more time is required for a large sized fish to equilibrate to warm water than a small fish (EPA 1999) and in a population, there is always some degree of variation in water temperature tolerance that may allow members at the extremes of the distribution to withstand water temperatures different from the majority of the population. Additionally, water temperatures tolerated for a few days may not be indicative of water temperatures providing sustainable fisheries because of longer-term effects of disease, growth, competition, or avoidance effects (EPA 1999). For all the above discussed reasons, different water temperature recommendations that include a combination of laboratory data on water temperature tolerance and field data on temperature effects on spawning, incubation and initial rearing will be developed from published reviews and utilized.

Assessment of Feather River Water-Temperature Effects on the Distribution of Chinook Salmon Spawning. It is expected that the analysis of the data collected in the most recent (2000-2002) DWR carcass surveys for Chinook salmon, in conjunction with the detailed site-specific water temperature records collected by SP-W6, *Project Effects on Temperature Regime*, will provide useful inferences on potential effects of water-temperature on the spawning distribution of Feather River Chinook salmon spawning. Contingent on data availability, it is expected that the analysis may provide answers to questions such as:

- What is the relationship, if any, between the amount of spawning per month or week within a surveyed river reach and the water temperatures at the site?
- Does spawning start earlier in the reach between the Fish Barrier Dam and the Thermalito Afterbay River Outlet than in the lower Feather River reach below the outlet, and if so, can be inferred that the difference in spawning initiation is related to water-temperature differences between both reaches?
- Does the difference in percent spawning in both reaches change as the difference in temperature between both reaches decreases?
- Would increasing flows between the Fish Barrier Dam and the Thermalito Afterbay River Outlet causewater temperatures below the outlet to be cool enough to allow more Chinook salmon spawning in this reach?

To perform the assessment and provide answers to the questions above, the detailed records gathered during the Chinook salmon carcass surveys performed by DWR since 2000 will be processed to provide site-specific monthly and weekly counts of numbers of Chinook salmon fresh carcasses and of estimated numbers of spawned and un-spawned female Chinook salmon. These monthly and weekly counts and estimates will be then compare with the site-specific water temperature data collected by SP-W6 to assess potential relationships between the two variables. Different statistical tools such as ANOVA, regression analysis or t-tests will be used as required by the hypothesis under test and the quality and extent of the available data.

General Evaluation of Potential Water-Temperature Effects on Egg and Alevin Survival. The information on recommended water temperatures for egg incubation and egg and alevin survival gathered through the literature review will be contrasted with the available historic and recently collected records of water temperatures for the known Feather River salmonid spawning grounds compiled by SP-W6, *Project Effects on Temperature Regime*, and to intragravel water temperature records collected by SP-G2 and compiled by SP-F10 under Task 2A to provide a general assessment of potential effects of Feather River water temperatures on egg and alevin survival. Contingent on data availability, it is expected that the evaluation will provide answers to questions such as:

- How often did water temperatures in the reach between the Fish Barrier Dam and the Thermalito Afterbay River Outlet meet the water temperatures recommended by the literature for the survival of eggs and alevins of Chinook salmon and of steelhead?
- How often did water temperatures in the reach between the Thermalito Afterbay River Outlet and Honcut Creek meet the water temperatures recommended by the literature for the survival of eggs and alevins of Chinook salmon and of steelhead?
- Are intragravel water temperatures in current Feather River spawning grounds adequate to allow the survival of eggs and alevins of Feather River Chinook salmon and of steelhead?
- Can it be expected that a change in the current temperature regime associated to the ongoing operation of Oroville facilities may be beneficial to the survival of eggs and alevins of Feather River Chinook salmon and of steelhead?

The contrast between river and intragravel water temperature records and the different thermal regimes recommended for spawning and egg incubation of salmonids in the literature will provide an initial evaluation of potential current project water temperature-related effects on salmonid egg and alevin survival. On the other hand, comparisons between the thermal regimes recommended in the literature and water temperature model outputs under different operational scenarios (obtained from SP-E1.5, *Feather River Temperature Model Development*) may provide answers to expectations of increasing the survival of eggs and alevins of Feather River fall-run and Chinook salmon exhibiting spring-run life history and of steelhead by manipulating operations at the Oroville facilities.

Modeling of Water-Temperature Impacts to Early Life Stages of Feather River Chinook Salmon. Contingent on the availability and quality of water temperature and fish data, equations describing the relationships between water temperature and early life stage mortality will be developed. These equations will then be used to assess potential water temperature-related impacts to the early life stage of Chinook salmon. If possible, this analysis will be similar to USBR's Sacramento River Chinook Salmon Mortality Model. USBR has developed a Sacramento River Chinook Salmon Mortality Model applicable to all four runs of Chinook salmon. Water temperature input to the Sacramento River Chinook Salmon Mortality Model consists of monthly mean water temperatures at nine locations between Shasta Dam and Vina Bridge. Annual early lifestage survival (the complement of mortality) is estimated for the Project for a selected period of record. Model output represents the percentage of potential emergent fry produced, based on all eggs brought to the river by spawning adults, that would survive under the water temperature regime that would occur under a model simulation. The model calculates water temperature-induced mortality (the percentage of potential emergent fry lost as a result of water temperature-induced mortality of pre-spawned eggs, fertilized eggs incubating in the gravel, and pre-emergent fry). Losses for each of these three early lifestages are then tallied by the model and output as a percent loss (mortality) from egg potential (all eggs brought to the river by immigrating adults) for each year modeled. The complement (i.e., survival = 100 - mortality) of these calculated percent losses is then discussed for assessment purposes.

Task 2D— Evaluate flow fluctuation-related effects on redd dewatering

Flow fluctuations are rapid changes in stream flow that occur regularly over short periods (minutes, hours or days) of time. Flow fluctuations are generally associated with planned daily operations of hydroelectric power generation or deliveries to water diverters. Flow fluctuations also may occur at any time due to natural events (e.g., storms, floods), failures, or emergency shutdowns. Flow fluctuations have the potential to result in redd dewatering. Redd dewatering is the process by which the water level in a salmonid spawning ground drops below the level of the eggs. Redd dewatering may desiccate the eggs and cause egg, embryo or alevin mortality, and may also reduce the development rate of embryos.

Flow requirements for the Feather River are determined by the August 26, 1983 agreement between DWR and DFG, Concerning the Operation of the Oroville Division of State Water Project for Management of Fish & Wildlife. This agreement states that a flow of 600 cfs is to be released into the main channel of the Feather River from the Thermalito Diversion Dam (i.e. diversion dam outlet, diversion dam power plant, and the Feather River Fish Hatchery pipeline) for fishery purposes. In the reach of the Feather River downstream of the Thermalito Afterbay outlet, water flow is supplemented by releases from the Thermalito Afterbay outlet to maintain a minimum flow downstream to the mouth of the Feather River at Verona. During the month of September, the flow requirement the reach of the Feather River extending from the Thermalito Afterbay outlet is 1000 cfs. During the months of October through February, the minimum flow requirements for this reach are 1,200 or 1,700 cfs, depending on the percentage of unimpaired runoff of the Feather River near Oroville from the preceding water year as compared to the normal unimpaired runoff of 1,942,000 acre-feet (mean of 1911-1960). Additionally, there is a requirement that specifies that if the average highest one hour flow of the combined project releases exceeds 2,500 cfs between October 15 and November 30, with the exception of releases for flood control, accidents, project failure, major or unusual maintenance, then the minimum flow for the period of October through March shall not be less than 500 cfs of the average highest one hour flow. The 2,500 cfs threshold was envisioned to protect redds in the event that spawning occurs in the overbank areas. If flow during the October through February period was 1700 cfs, flow must remain at 1700 cfs through March. If flow during that time were 1200 cfs, the flow requirement is 1000 cfs in March. The project is usually operated such that only one major reduction in flow occurs downstream of Thermalito Afterbay outlet during the months Chinook salmon redds are present in the Feather River (generally just before October 15). Additional flow fluctuations may occur in the reach of the Feather River downstream of Thermalito Afterbay outlet when steelhead redds are present in the Feather River, but observations suggest that steelhead do not spawn downstream of the Thermalito Afterbay outlet.

The objective of this task is to evaluate the potential for, and the impact of, redd dewatering due to flow fluctuations in the Feather River. DWR is currently conducting a redd dewatering and juvenile stranding survey in accordance with the NMFS 2000 Biological Opinion for the operation of the Central Valley Project and State Water Project. In the first year of the stranding survey (2000-2001), 23 dewatered redds were identified during flow reductions occurring during the steelhead and Chinook salmon spawning season (DWR, unpublished data). Based on carcass survey estimates of number of spawned females, and assuming that each female spawns only once, the loss of 23 redds represents 0.05% of the redds in the Feather River (DWR, unpublished data). A 1999 survey during a scheduled flow reduction from 4500 cfs to 2300 cfs identified 23 completely dewatered redds and 9 partially dewatered redds (DWR, unpublished data). In order to build on existing data, the redd dewatering survey conducted in accordance with the NMFS Biological Opinion will be continued. This will allow continuity with existing data to be maintained. Because existing data suggests that the total number of redds dewatered constitutes minimal (0.05%) impact to salmonid populations in the Feather River, the estimate of the effect of redd dewatering will be highly conservative in that a dewatered redd will be considered to have suffered 100% mortality.

The objectives of the redd dewatering survey includes surveying spawning sites to determine the number of redds dewatered or partially dewatered by reductions in flow, describing the physical and biological conditions associated with redd dewatering, and estimating the biological significance of redd dewatering in the Feather River. Redd dewatering surveys will focus on the reach of the Feather River extending from the Thermalito Afterbay to the confluence of Honcut Creek. The rationale for establishment of this geographic area is that flows in the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet are kept relatively constant at 600 cfs, and therefore little flow fluctuation occurs in this reach of the river and there is little potential redd dewatering. However, the reach of the river extending from the Thermalito Afterbay outlet to the confluence of Honcut Creek is more complex and flow is more variable. Under normal operations, this area has the highest potential for redd dewatering and will therefore be the focus of redd dewatering investigations.

Conceptual Framework. Flow fluctuations that may occur under flood control releases, scheduled operation-maintenance flow reductions, storm events, failures or emergency shutdowns may subject redds to dewatering**.** Redd dewatering may lead to egg, embryo or alevin mortality**.** If the proportion of redd dewatered is high during the salmonid spawning season, the production of salmonid new recruits may be affected**.**

Redd Dewatering Surveys. During the salmon and steelhead spawning seasons, and coinciding with DWR carcass and redd surveys (Task 2B), major spawning riffles will be visited after each reduction in flow**.** The major riffles to be sampled will be based on the evaluation of existing information on Feather River salmonid spawning, previous redd dewatering survey results, and evidence provided by the concurrent carcass and redd surveys (Task 2B). After a reduction in flow, field crews will visit major spawning riffles where dewatering may occur. The frequency of sampling will depend on changes in project operations. As stated earlier, in the reach of the river from the Fish Barrier Dam to the Thermalito Afterbay outlet, flow is generally held at a constant flow of 600 cfs. Therefore, flow reductions are expected to be minimal in this river reach. Redd dewatering would only be expected to occur during flood control events or during the summer, when flows may be manipulated to meet temperature criteria. In the river reach extending from the Thermalito Afterbay outlet to the confluence with Honcut Creek, flow are frequently reduced in 200 or 500 cfs increments per 24 hour period. After each flow reduction, field crews will visit major spawning riffles and will record the river mile, flow and number of exposed redds**.**

Dewatered salmon redds are identified and counted based on two criteria. For a redd to be considered dewatered it must either: 1) be in an area isolated from or lacking flowing surface water, or 2) have some portion of substrate not completely covered by water. If, for example, a 300mm piece of cobble were partially exposed in a salmon redd, that redd would be considered dewatered. Minimum water depths are not used, because they are difficult to apply in salmon spawning areas where the substrate surface is very uneven. This criteria is intended to be very conservative, and as such, may include redds that have not been deleteriously impacted by a flow reduction. As mentioned earlier, redds considered dewatered will be assumed to suffer 100% mortality.

Analyses. To assess how the project operations potentially affect flow fluctuations in the Feather River and how those, in turn, affect redd dewatering, a relationship between stage/discharge and the temporal distribution of redds in the Feather River will be developed. This relationship will then be used to evaluate how the project operations effects on stage/discharge potentially impact the dewatered redds on a temporal basis. The relationship will be developed for only those months where redds are present in the river. The temporal distribution of dewatered redds will be compared to the flow at which each redd was determined to be dewatered. This comparison will allow estimation of the number of redds which may be expected to become dewatered under various operational scenarios. Additionally, an existing flow model for the Feather River (based on PHABSIM analysis) provides another tool for evaluating flow effects on salmon redds. The flow model allows prediction of the number of redds that have been dewatered as the result of a given flow change. This prediction is based on known relationships between flow and river elevation (stage) at a number of transects on the Feather River. This stage-flow relationship along with information about the typical distribution of salmon redds provides the basis for the predictive model. In past comparisons, flow-stage model predictions have proven to be consistent and accurate when compared with direct counts of dewatered redds.

Task 3—Evaluation of project effects on juvenile rearing of salmonids in the Feather River

Juvenile rearing in the Feather River will be evaluated for steelhead, spring-run and fall-run Chinook salmon. In general terms, juvenile rearing can be defined as the period of time that salmonids spent in the river of origin from fry emergence to the onset of the seaward migration. The extent of the rearing period in their natal river can be highly variable among salmonids, depending on species, race and population. For many populations the rearing period is brief with most juveniles leaving their natal rivers as fry or parr. For others, the rearing period is longer with juveniles leaving their natal rivers as smolts.

In the Feather River, juvenile Chinook salmon emigrate from November through June, with peaks from late January through mid March. Results from 1998-2001 DWR rotary screw trap (RST) surveys and from 1999-2001 snorkel surveys suggest that most Chinook salmon do not smolt upstream of Live Oak (RM 42). For example, 96.6% of the salmon trapped by the RST located at RM 60.1 and 81.4% of the salmon trapped by the RST located at RM 42 consisted of juveniles with fork lengths smaller than 50 mm (DWR unpublished data).

Similarly, for juvenile steelhead that rear in the Feather River year-round (DWR and USBR 2000), data from recent DWR snorkel and RST surveys suggest that most steelhead rearing occurs upstream of the Thermalito

Afterbay River Outlet (RM 59), principally in areas along the margins of the channels and under riparian cover and in secondary channels under riparian cover (DWR and USBR 2000). For example, 99.8% of all the juvenile steelhead observed in the DWR 1999-2000 broad scale snorkel surveys were observed upstream of the Thermalito Afterbay River Outlet, and 98% of all juvenile steelhead caught in the 1999-2001 RST surveys were caught at the RST located at RM 42 (DWR unpublished data). Moreover, in the DWR 1999-2000 broad scale snorkel surveys, 96% of all juveniles observed upstream of the Thermalito Afterbay River Outlet and 78% of all juveniles observed downstream of the Thermalito Afterbay River Outlet were young-of-the-year (YOY) fish with fork lengths smaller than 100 mm (DWR unpublished data).

Task 3 will provide information on the direct and indirect potential effects of water temperatures, habitat availability and suitability, and habitat complexity on rearing juvenile anadromous salmonids. This task will characterize and evaluate anadromous salmonid juvenile rearing habitat (Subtask 3A) and evaluate the effects of Feather River water temperatures on juvenile rearing (Subtask 3B). In addition, Task 3C will evaluate flow fluctuation events that may result from project operations, and their effect on anadromous salmonid juvenile rearing. The effects of Feather River flow levels on juvenile rearing will be studied under SP-F16. The information gathered from this task will provide an assessment of how potential project effects on the factors listed above may affect juvenile rearing of anadromous salmonids in the Feather River.

<u>Task 3A—Identify relative abundance and distribution of rearing juvenile salmonids, and determine habitat characteristics for rearing juvenile salmonids in the Feather River</u>

Chinook salmon juveniles require sufficient cover, space, and food supply during rearing (DWR 2001). In order to provide adequate protection from predators and adequate supply of invertebrate prey, habitat should include overhead cover such as undercut banks, logs, woody debris, and dense overhead canopy (DWR 2001). When juvenile Chinook salmon are in fresh water they are drift feeders, consuming various aquatic and terrestrial insects, crustaceans, and larvae (CALFED 1998).

Steelhead fry utilize shallow, well-protected areas associated with the stream margin following emergence from gravel (DWR and USBR 2000). Steelhead fry tend to inhabit areas containing cobble-rubble substrate, a water depth of 8 inches (but will utilize water two to 14 inches deep), and water temperature ranging from 45°F to 60°F (DWR and USBR 2000; CALFED 1998). Parr prefer a water depth of 10 inches but utilize water 10 to 20 inches deep (CALFED 1998). Older juveniles inhabit riffles, with larger juveniles utilizing pools and deeper runs (DWR and USBR 2000). Surveys document that steelhead ranging from 55 to 75 mm in fork length size by August and September move away from the channel margins and into higher velocity areas in the channel (DWR and USBR 2000).

Conceptual framework. Ongoing operation of the Oroville Facilities may affect water temperatures, instream flows, flow fluctuations, and other factors that influence rearing juvenile anadromous salmonid habitat availability and suitability, distribution and abundance.

Review of fish distribution and abundance data and habitat characterization.
This task will consist of an evaluation of available data describing juvenile rearing anadromous salmonid distribution and habitat characterization. The evaluation requires documenting and identifying the relative abundance and distribution of rearing juvenile anadromous salmonids among habitat types, months, and reaches in the Feather River, accompanied by characterization of Feather River juvenile anadromous salmonid

rearing habitats in terms of environmental characteristics such as water temperature, water depth and velocity, substrate type, availability and type of cover, and channel type. Available information describing the location of rearing juveniles in the Feather River downstream of the Fish Barrier Dam and environmental conditions (i.e., water temperature, depth, velocity, substrate, cover and channel type) under which juvenile salmonids occur will be compiled and summarized. This review will be conducted by the October of 2002.

Ongoing field studies. Field studies designed to supplement the information obtained from the reviews will be continued. The intent of continuing ongoing field studies is to gather data necessary to identify a relationship between the relative abundance and distribution of juvenile salmonids and habitat conditions in the Feather River. Additionally, habitat suitability criteria for rearing juvenile anadromous salmonids in the Feather River will be developed using data from the field studies. Once the temporal distribution of rearing juvenile anadromous salmonids has been identified and juvenile rearing habitat has been characterized, the relationship between fish distribution and habitat characteristics can be applied to evaluate potential project effects on fish distribution and abundance.

Field surveys will be performed from March through August to acquire a depiction of juvenile anadromous salmonid rearing habitat in the Feather River, as well as juvenile anadromous salmonid distribution. The identification of rearing juvenile distribution and habitat-related environmental conditions will be accomplished by snorkel surveys conducted by divers. The area that will be surveyed extends from the Fish Barrier Dam to the confluence with Honcut Creek. The geographic extent of the snorkel surveys is based in the preliminary results of the 1999-2001 snorkel surveys that suggest a consistent and dramatic decrease in the numbers of rearing salmonids as the distance from the Thermalito Afterbay Outlet increases (DWR unpublished data). Moreover, the efficacy of snorkel surveys is greatly reduced downstream of Honcut Creek because of the sandy nature of the river substrate that increases turbidity impairing the divers' ability to count fish and correctly differentiate fish species and size.

The snorkel surveys will record the number of fish and size (fork length) by species, and the habitat unit utilized, substrate, water temperature, water depth, and focal-point velocity (additional detailed description given below). The race of Chinook salmon observations (i.e., spring-run or fall-run) will be determined a posteriori by using the divers' size records and size-at-time tables (Green 1992). Continuous water temperatures will be recorded with a network of in-situ temperature loggers by SP-W6. Ambient temperatures and weather condition will be recorded for the reaches extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek. In order to maximize the effectiveness of snorkel surveys, sampling will be conducted on three physical scales: broad, intermediate, and fine. Each type of survey will collect slightly different data to fulfill information needs. Broad scale surveys will cover the entire length of the study area in a short period of time. Intermediate-scale surveys will take place monthly and will sample river reaches covering a single riffle-pool sequence (200-500 m long). Fine-scale surveys will consist of short reaches (≅25 m). The results of the broad-scale survey will be used to define strata for the selection of sites that will be sampled for fine-scale sampling. The specific protocols for each type of snorkel survey are described in detail below.

Broad-scale snorkel surveys will be conducted once every year in June to maintain consistency with previous survey results. These surveys will provide a snapshot of overall abundance and distribution of anadromous salmonids in the Feather River. Each broad-scale survey will take about two weeks to complete. Snorkel observations will generally be made in a downstream direction, as currents are strong in many areas. Three to six divers will be distributed among three transects: left bank, right bank and center channel. Divers will use plastic dive slates to mark information on individual fish or schools of fish located. The slates will be used to record the approximate fish size (fork length to the nearest mm), number of fish, substrate type, cover and habitat type (hydro-geomorphic units). Maps depicting habitat type (hydro-geomorphic unit), cover classification, and channel type will be provided to SP-F10 by SP-G2, as specified in section 7.0, Coordination and Implementation Strategy. Location (specific habitat unit) and number of fish observed at that location will be marked on habitat maps for determination of distribution and abundance of rearing juveniles. Additionally, dominant substrate type will be classified visually using the Brusven index as illustrated in Table 1, and visual estimations will be compared with the results of both Wolman pebble counts and gravel sieving occurring in SP-G2 to determine the accuracy of visual assessment. A recorder (in a boat or wading) will follow to transcribe the data onto data sheets. Effort at each sampling site will be recorded based on the time sampled, area covered and the number of divers.

Table 1. Example of Substrate Classification System to Record Dominant Substrate Type Used by Feather River Anadromous Salmonid Species

Code	Substrate Description
1	Fines – Small Gravel (0-50 mm) (0 – 2 in)
2	Small – Medium Gravel (50 – 150 mm) (2 – 6 in)
3	Medium – Large Cobble (150 – 300 mm) (6 – 12 in)
4	Boulder (> 300 mm) (> 12 in)

Source: Brusven (1977)

Intermediate-scale surveys will occur monthly, from March through August. These surveys will cover nine permanent sampling stations, six in the reach extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and three in the lower reach downstream of the Thermalito Afterbay River Outlet. Each sampling station will cover at least one riffle-pool sequence. These nine stations will be the same stations that are currently in use by DWR in order to maintain consistency with previous studies. Observations of fish and habitat will be performed as for the broad-scale surveys. Water depth, water temperature, water velocity, and substrate will be measured in ten systematic transects at each station. Habitat transects will be repeated if conditions such as river stage, flow or temperature change between surveys. This habitat information will be used to generally describe and quantify the habitat for juvenile anadromous salmonids, as well as estimate the amount of total available habitat, whether or not occupied by anadromous salmonids. This information will be utilized to develop explanatory mechanisms for potential project effects on rearing juvenile anadromous salmonid habitat, and then to correlate the potential project effect on rearing salmonid distribution.

Fine-scale survey sites are chosen randomly within riffle and glide habitat units. This information will be used to characterize and quantify microhabitat availability and usage. This data will also enhance our ability to elucidate the influence of factors such as river mile, water temperature, riparian vegetation and channel type on the abundance or occurrence of fish species. Fine-scale surveys will occur monthly from March through August. Sampling locations will be selected randomly within riffle and glide habitat units, that were identified and mapped in prior surveys. At a minimum, the Feather River will be divided into two reaches extending from the Fish Barrier Dam to the Thermalito Afterbay River Outlet and from the Thermalito Afterbay River Outlet to the confluence with Honcut Creek. Each section to be surveyed will run parallel to one riverbank, covering an area 25 meters long and four meters wide. Two divers will survey the reach by working upstream and marking the number, species, size, and position of all fishes observed. For each fish observed, the water depth at which the fish was observed and the focal-point velocity also will be recorded. After the fish survey is completed, the crew will gather habitat data by recording water depth, average velocity, water temperature, substrate, cover and habitat types at 36 points, evenly distributed within the 25 by 4-meter transect. Information for individual fish will be used to construct habitat suitability curves.

Analysis. The broad-scale surveys are designed to allow determination of distribution and abundance of rearing juvenile anadromous salmonids. Results of the survey will be added to the habitat maps provided by SP-G2 by integrating the total number of each species observed in each individual habitat unit. This integration will allow estimation of the number of rearing juveniles by species, the distribution of rearing juveniles by species, and the number of rearing juveniles by river reach or habitat unit. Using data from this task, the distribution of rearing juveniles by species may be correlated with variables that are potentially affected by project operations, including water temperature and dominant substrate particle size. A correlative estimation may suggest how potential project related effects influence fish habitat, and how the potential effect on fish habitat relates to fish distribution throughout the Feather River from the Fish Barrier Dam to the confluence with Honcut Creek.

The intermediate-scale snorkel surveys are designed to provide more detailed and specific habitat-related information, including both temporal and geographic distribution information. By repeating the survey every month for six months, it will be possible to estimate temporal distribution of rearing juveniles by species. By summarizing the findings of this survey by month, it will be possible to determine if the geographical distribution of rearing fish changes over the summer months. The data will be used to determine if the number of rearing individuals is relatively constant at each of the nine stations, or if the number of rearing juveniles spatially changes downstream from March through August. Additionally, by overlaying habitat distribution information at an individual station over six months, it will be possible to determine whether rearing juveniles prefer similar habitats throughout the entirety of the rearing period, or whether rearing juveniles habitat preferences change throughout the rearing period. Additionally, the distribution of rearing juveniles by species may be correlated with variables that are potentially affected by project operations, including water temperature, water depth, water velocity, and dominant substrate particle size as specified for the broad-scale survey. A correlative estimation may suggest how and where potential project-related effects influence fish habitat.

Fine-scale surveys are designed to collect more detailed information to characterize and quantify microhabitat availability and usage, and consequently enhance our ability to elucidate the influence of factors such as river mile, water temperature, riparian vegetation and channel type on the abundance or occurrence of fish species.

Although the snorkel surveys will not extend downstream of the confluence with Honcut Creek for the reasons stated earlier, the information on habitat characteristics gathered during the current and previous snorkel surveys will be applied to cross-sectional information from SP-G2 to infer which areas of the Feather River between its confluence with Honcut Creek and its confluence with the Yuba River are more likely to have similar habitat characteristics and fish use. These inferences will in turn help to identify locations for potential

PM&E measures. If within the two-years timeframe of SP-F10 the Feather River flows are high enough to inundate the large floodplains, defined as the areas adjacent to the active river channel that are within the channel constrained by the levee, extending upstream and downstream of the confluence of the Feather and Bear River, a seining and mark-recapture survey will be conducted in the inundated floodplains and adjacent areas to determine whether juvenile salmonids actively rear in the inundated plain. By “actively rear”, we mean that the juveniles not only move to the inundated areas but also that they grow during their sojourn in the flooded area.

Four sites in the inundated floodplains and four in the Feather River main channel, upstream and downstream of the confluence of the Feather and Bear rivers, will be randomly selected for biweekly seining activities. Seining samples will consist of 3 to 5 short sweeping seine hauls. A maximum of 50 linear meters will be sampled for each location and sampling period. At each sampling location and time, the catch will be separated by species and counted. The fork length of caught juvenile salmonids will be recorded to the nearest millimeter. If the catch of juvenile Chinook salmon exceeds 1,000 fish, a random sample of no less than 1,000 fish will be measured for length. During the hauls performed in the inundated floodplain in the first sampling week, all juvenile steelhead captured and a random sample of Chinook salmon juveniles of no less than 1,000 fish will be weighed, measured (fork length) and uniquely marked with a photonic color tagging gun and returned to the river in the approximate location of their original capture. During hauls performed in subsequent weeks at both the floodplain and main channel sites, all tagged fish recaptured with photonic color tags will be measured, weighted and recorded by tag code description and returned to the river.

Seining data will be analyzed in several ways to provide insight on the use of the inundated floodplains as well as on the growth of juveniles that rear in the floodplains. The comparison of the biweekly length frequency distributions of the fish caught at the floodplain sampling sites versus the length frequency distributions of the fish caught in the main channel will provide a general assessment of the temporal distribution of the fish at both areas. Moreover, the proportion of tagged fish recovered in the biweekly seining samples may provide a first appraisal on the fidelity of the juveniles to the floodplain sites. Finally, contingent on the dimension of the species-specific recapture rates, the recaptures of tagged juveniles will be used to estimate species-specific growth rates.

It was mentioned earlier that, based upon unpublished results from the 1998-2001 DWR rotary screw trap (RST) surveys and from the 1999-2001 snorkel surveys, most Chinook salmon do not appear to smolt upstream of Live Oak (RM 42), and leave the Feather River upper reaches as fry, mostly between January and mid March. However, a small proportion of Chinook salmon juveniles appears to prolong their stay in the upper reaches, migrating later in the season (April through June) as silvery parr or smolt. For example, 1.8% and 0.2% of the salmon trapped by the RST located at RM 60.1, and 12.7% and 1.26% of the salmon trapped by the RST located at RM 42 consisted of juveniles classified as silvery parr and smolt, respectively (DWR unpublished data). These preliminary results suggest the possible existence of two rearing strategies for Feather River Chinook salmon juveniles: 1) leaving the upper Feather River reaches at the early stages of fry and parr, and 2) leaving the upper Feather River reaches later in the season, at larger sizes (i.e., as silvery parr or smolt). If these two strategies are effectively available to Feather River Chinook salmon juveniles, then the question arises on whether there is a difference in success, measured as adult returns, between both strategies.

Task 3B - Evaluate Feather River water temperature effects on salmonid juvenile rearing

Rearing juvenile salmonids are more temperature tolerant than are earlier lifestages (DWR and USBR 2000). Naturally spawned Feather River steelhead have been observed to rear successfully at water temperatures below 65°F (DWR and USBR 2000). Young-of-year Feather River steelhead have been observed rearing in habitats where average daily water temperature was 63°F, and where daily maximal water temperature exceeded 66°F (DWR and USBR 2000). Laboratory studies on Feather River hatchery and naturally spawned steelhead suggest that rearing juveniles prefer temperatures of 62-68ºF (Cech and Myrick 1999, Myrick 1998). Average monthly water temperatures in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet range from 47°F in winter to 63-65°F in the summer. Water temperatures downstream of the Thermalito Afterbay outlet are generally warmer, with the maximum mean daily water temperature at the Thermalito Afterbay outlet reaching approximately 70°F in the summer (DWR 2001). Because daily summer water temperatures generally exceed 70°F below the Thermalito Afterbay outlet, it is unlikely that steelhead rear in the lower reach of the river (DWR and USBR 2000). Snorkel surveys have confirmed that the area below the Thermalito Afterbay outlet harbors essentially no rearing steelhead (DWR and USBR 2000). Because juvenile steelhead rear in the river all year and are expected to be in the river during months when increased water temperatures are probable, field experiments have been proposed to investigate the effects of water temperatures on rearing juvenile steelhead.

Rearing juvenile Chinook salmon are also more temperature tolerant than earlier lifestages (DWR and USBR 2000). Rearing juvenile Chinook may tolerate temperatures as warm as 60 to 65°F, but they exhibit a higher susceptibility to disease at 65°F compared to 60°F (DWR and USBR 2000). Because RSTs at Thermalito and Live Oak suggest that most juvenile Chinook salmon emigrate as post-emergent fry soon after hatching (principally November through January), Chinook salmon juveniles are not expected to be rearing in the river during months in which increased water temperature is probable. Therefore, field studies for temperature requirements for rearing Chinook salmon in the Feather River will not be conducted.

A suite of data collection efforts has been initiated by DWR to investigate the effects of temperature on Feather River rearing steelhead juveniles. Completed studies include a laboratory study investigating the thermal preferences of rearing Feather River Hatchery and naturally spawned Feather River juvenile steelhead conducted by Cech and Myrick (Cech and Myrick 1999). Using thermal gradients, researchers observed that naturally spawned and hatchery steelhead preferred water temperatures ranging from 62.6ºF and 68ºF (Cech and Myrick 1999). Additional existing data includes observational data from DWR snorkel surveys where YOY steelhead were observed rearing in areas with daily average water temperatures of 63ºF and with a daily maxima water temperature of 66ºF (DWR unpublished data as cited in DWR and USBR 2000). To complement the existing laboratory study and the continued gathering of observational data by snorkeling (Task 3A), three additional studies are proposed in this task.

The first is a literature review designed to compile the temperature recommendations for rearing juvenile steelhead from a variety of laboratory and field experiments. This task will also include summarizing existing site-specific observational data and the laboratory study conducted on Feather River juvenile steelhead. The enclosure experiment and accompanying seining experiment proposed in this task are two additional components of the investigative strategy employed to determine the thermal tolerance of rearing steelhead. These two experiments are designed to provide Feather River-specific field-generated data that will complement the existing laboratory and literature data regarding the effects of water temperatures on rearing juvenile steelhead. Together, the existing and proposed studies will facilitate a complete evaluation of the effects of water temperatures on Feather River juvenile steelhead during the rearing period. As discussed in Task 1D, because of differences in assumptions and techniques used in field and laboratory experiments regarding temperature recommendations, it is important to consider data gathered in both the laboratory and in the field so as to not bias the results by relying on a temperature recommendation developed using a single technique. The field studies proposed here ensure that evaluation of water temperature effects on rearing steelhead in the Feather River will include both field and laboratory components.

Conceptual framework. The operation of the Oroville Facilities may affect water temperature, which may influence rearing juvenile salmonids. Exposure of rearing juvenile salmonids to high water temperatures may result in acute direct mortality or in sublethal chronic thermal stress that can be evidenced through indicators such as disease outbreaks, reduction in growth and food conversion efficiency, loss of appetite, hyperactivity or disorientation, and secretion of adrenaline and other stress-related hormones.

Literature review of water temperature effects. A literature review of studies focused on the effects of water temperature on rearing juvenile salmonids will be conducted. This review will include studies based on both laboratory and field experiments, as well as reported observations on water temperature-related effects, including the above-mentioned studies specific to Feather River steelhead. The reviewed information will be assessed and summarized in species-specific tables showing critical temperature ranges and resulting effects, indicating the origin of the information (laboratory or field experiment, race/stock of fish used in experiment), comments on the reliability of the information source and applicability of the temperature recommendation to Feather River salmonids. Results of the literature review will be compared to water temperature tolerances observed through the enclosure experiment and the seining experiment described below.

To evaluate the effect of water temperature on juvenile steelhead rearing in the Feather River, two types of field studies will be performed: enclosure experiments and seining.

Field work for enclosure experiment. Each enclosure experiment will be conducted for a minimum duration of three months. Riffles at two different locations along the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet will be selected for placement of experimental enclosures. The primary criteria for the selection of the two locations will be water temperatures during the three months of the experiment. The two potential locations should provide a detectable water temperature gradient during the three months assigned for the experiment. Initially, it can be expected that one of the locations will be in rearing grounds close to the Fish Barrier Dam, where cooler waters are expected. The second location will be in proximity to the Thermalito Afterbay outlet, where warmer waters can be expected. Treatment replication will be provided by placing three enclosures at each location. Special care will be taken to ensure that water depth, velocity, and cover are similar for each enclosure site. Moreover, care will be taken to ensure the absence of predators in the enclosures. In-situ water temperature loggers will be attached to each enclosure to ensure accurate water temperature readings at each site.

Each enclosure will consist of three expanded metal panels and two round-rod wire gates and will be lined with hardware cloth. It will be stabilized in the river by stakes attached to the frame and with rocks placed inside the enclosure. Each enclosure will measure 2.6m x 1.3m x 0.75m. As food may be a limiting factor in an enclosure, territory size (what an individual can defend) will be the basis for determining the number of steelhead that will be placed in each enclosure (loading density). Loading density will be determined using the following equation (Grant and Kramer 1990):

$$\log_{10}\text{territory size} = 2.61 \log_{10}\text{length} - 2.83$$

where territory size = m^2 and length = maximum fish length in cm. Maximum fish length attained throughout the period of study is anticipated to be 7.5 cm, based on expected size of hatchery fish at the beginning of the experiment and anticipated growth over the course of the study. The area of the enclosure ($3.38m^2$) was then divided by territory size to determine to number of fish per enclosure.

Twelve hatchery-reared steelhead juveniles of roughly similar size and health condition will be placed in each enclosure for approximately three months. Before placement in the enclosure each fish will be uniquely marked with photonic color tagging gun. At the beginning of the experiment, each individual will be measured and weighed. Each enclosure will be monitored and cleaned daily to prevent debris accumulation. Any dead fish encountered during the daily visits will be measured, weighted, and examined for exterior general appearance. The tag, length, weight, and general appearance of each dead fish, and the date will be recorded. Dead individuals will be preserved for histological laboratory analysis.

Every two weeks, invertebrate drift samples will be collected at each site to evaluate potential differences in food availability between sites. Invertebrate drift will be sampled using a Hess substrate sampler in combination with a drift net sampler to evaluate whether or not there are differences in prey availability between the two enclosure sites. Methods for invertebrate drift and substrate sampling will be those proposed in Task 2B of SP-F1. If SP-F1 institutes a 12-month sampling procedure for assessment of the aquatic insect communities in riverine habitats, samples will be taken at each of the two enclosure sites throughout the enclosure experiment, in addition to the sub-areas, which will be chosen randomly for sampling. These two specific sites may require biweekly sampling.

During biweekly visits to the enclosures, each fish will be measured and weighed to monitor growth and general physical appearance. Upon completion of the experiment, all fish will be measured, weighed, and sacrificed for laboratory analysis of stomach contents and indicators of fish condition (see Analyses). Stomach contents will be analyzed as described in SP-F1, Task 2C. Identification to the lowest practical taxon (generally genus) and enumeration of stomach contents and invertebrate drift samples will be completed at the DWR Aquatic Macroinvertebrate Laboratory at Red Bluff. Invertebrate drift samples will be analyzed in conjunction with stomach contents to identify potential differences in growth due to differences in available prey at each site. The purpose of the comparison of invertebrate drift samples and stomach contents is to attain a gross estimate of the differences in prey availability between the two enclosure sites (see Analyses).

Analyses for enclosure experiment. Several indicators of fish condition will be assessed once fish have been sacrificed upon completion of the enclosure study. Growth rates of salmonids rearing can indicate overall fish condition and health (Castleberry et al. 1991). Additional indicators of fish health and condition (RNA-DNA ratios, lipid content, and histological analysis) can also be assessed and compared in-river conditions, such as water temperature, to provide another measure of fish response to varying environmental conditions (Castleberry et al. 1991). The cellular ratio of RNA to DNA provides an indirect estimate of the rate of fish growth. At the cellular level, the amount of DNA is constant, but the level of RNA changes in direct proportion to protein synthesis. Thus, RNA-DNA ratios provide an estimate of cellular protein synthesis. Estimation of lipid content indicates the stored energy fish hold in reserve for future growth. Fish with higher lipid content are generally considered healthier, with a greater change of survival than those with lower lipid content. Additionally, high lipid content suggests that the habitat provided adequate forage and sufficient environmental conditions (such as temperature). Histological analysis serves as a qualitative assessment of the nutritional status of the fish and provides a pathological evaluation. For additional discussion of the application of RNA-DNA ratios, lipid content, and histological analysis to assessment of physiological condition of salmonids, see Castleberry, et al. (1991).

Once fish have been sacrificed, the fish from each enclosure will be randomly assigned to one of three groups for laboratory analysis (4 fish per group). Fish in every group will have stomach contents removed for analysis as described in SP-F1. One group of fish will be preserved on dry ice and stored in the laboratory at -80°C for future RNA-DNA measurements. White muscle samples from the region anterior to the dorsal fin will be removed for RNA-DNA measurements. RNA and DNA will be quantified using standard analytical spectrophotometric (flourometric) methods (Castleberry, et al. 1991). Interpretation of RNA-DNA ratios should consider existing data describing the use of this ratio for comparing the effects of water temperature on growth when fish are exposed to different water temperature regimes (see Castleburry, et al. 1991 and references therein). The second group of fish will be frozen at -20ºC for storage until lipid analysis commences. Thawed fish will be weighed and then dried at 60ºC until they reach a constant mass. Fish will be placed in individual ether baths to extract lipids. Every other day (or as necessary) fish will be weighed and the ether bath will be replenished. Once fish achieve a constant mass, lipid extraction will be assumed to be complete. Fish will be dried and the difference between initial dry weight and final dry weight will be divided by the initial dry weight. Lipid content will be reported as percent dry body weight (Castleberry, et al. 1991). The third group of fish will be preserved in Bouin's fixative for histological analysis. Histopathological analysis will include assessment of stored glycogen as an indicator of nutritional status. Liver tissue will also be assessed to estimate feeding conditions, pathological status, energy storage, and overall fish health (Castleberry, et al. 1991). Organ volume may also be assessed and compared to cellular morphology to determine fish condition.

Survival, individual growth rates, final lengths and weights, RNA-DNA ratio, and lipid content will be compared between and within sites through using a nested ANOVA to test for differences between groups (enclosures) and between treatments (temperature). Power analysis suggests with planned sampling design indicates that we will be able to detect differences in coefficient of variation in weight as small as 6%, with a significance level of 0.05. Histological and pathological analyses will be compared qualitatively to identify gross differences in nutritional state and susceptibility to pathogens.

Several statistical approaches and indices may be used to compare the differences in prey availability and selectivity at different sites as each analytical technique has inherent associated weaknesses (Wootton 1990). Data for this comparison will come from stomach content analysis and invertebrate sampling. Ivlev's electivity index (Ivlev 1961) and nonparametric rank order comparisons (Kohler and Ney 1982) are among the techniques that may be used to compare the availability of food between the different enclosure sites and the prey selectivity associated with them. Ivlev's electivity index (Ivlev 1961) is a simple index requiring only data describing the relative abundance of prey in the gut and in the environment. This index generally is not useful for comparison between sites with different prey availability, but could be used to determine within group differences in areas with similar prey availability (i.e., same enclosure site) (Wootton 1990). Kohler and Ney (Kohler and Ney 1982) used nonparametric rank order statistical comparisons to compare the available food items to food items in the gut. This analysis could be used to compare the differences in available food between sites, and the differences in food preference between sites. The two approaches described will fulfill the objective of determining gross differences in prey availability between enclosure sites.

A pilot enclosure study was conducted June-August, 2001. Two enclosures were placed in the Feather River. One was located at the upstream most end of the main Feather River channel, and the other was located near the Thermalito Afterbay outlet. Individual weights and measurements were taken of the fish when the study began. The enclosures were visited weekly. Growth was observed even with temperatures near the Thermalito Afterbay outlet reaching 67ºF. No mortality occurred at either site. Unfortunately, at the end of August, the traps were vandalized and all fish escaped so comparison between the growth of fish in each of the two sites could not be attained. While data was not collected in the pilot study, it gave credibility to the effective use of the enclosures for future studies. The design for the enclosures has been reinforced to deter vandalism.

Site Fidelity and Growth of Wild Juvenile Steelhead. Wild, juvenile steelhead will be collected by seining in the vicinity (downstream of each enclosure site in the same riffle-pool sequence) of each enclosure. Seining samples will consist of 3 to 5 short sweeping seine hauls, a maximum of 50 linear meters will be sampled for each location and sampling period. Seining will be completed at these sites on a biweekly basis on the same day that enclosures are serviced. All steelhead captured will be weighed, measured (fork length) and uniquely marked with a photonic color tagging gun. Steelhead recaptured with photonic color tags will be recorded (by tag code description). After measurement and marking, fish will be returned to the river in the approximate location of their original capture.

The objective of the seine sampling is to provide information complimentary to the enclosure of hatchery steelhead, but that will not have artifacts of the enclosure experiment. Additionally, repeated seining is designed to investigate site-fidelity and growth of wild rearing juvenile steelhead in cases where fish are marked and recaptured. This study is not designed to determine distribution and abundance of juvenile steelhead in the Feather River (see Task 3A), but rather to provide site-specific field data that will augment the enclosure experiment by investigating wild steelhead site-fidelity and growth through mark-recapture methods. Seining data will be analyzed in several ways depending on the type of data acquired. Recaptures of tagged fish will be used to calculate individual growth rates and to estimate population survival rates. However, the probability of recapturing tagged fish is low, especially because we do not expect to be able to capture and tag more than 20 juvenile steelhead in a given sampling period. Without recaptures of tagged steelhead, gross growth rates will be calculated by comparing changes in length-frequency over time and between river locations (treatment sites). Length and weight measurements will also be used to calculate condition factors for each individual. These condition factors can be used to assess the general quality of rearing conditions and make contrasts between river locations. All of these results will be compared with results of the enclosure study, drift samples, and relevant scientific literature to provide context and increased confidence in the validity of results.

Task 3C--Evaluate project operation flow fluctuation effects on juvenile salmonid stranding

Objectives:

- Quantify on-going impacts of juvenile stranding and evaluate ability of current flow fluctuation guidelines in minimizing stranding events and impacts
- Quantify the amount of stranding potential area and resulting fish stranding that occurs during flow reductions between various flow levels
- Determine the biological significance of the proportion of the juvenile salmonid population loss due to stranding

Stranding Definition and Background:

Juvenile salmonids can become stranded on gravel bars or in isolated off-channel habitats as a result of flow fluctuations in rivers. Stranding from flow fluctuations occur on both natural and controlled rivers, but has usually been associated with large, rapid flow reductions related to reservoir and hydropower operations. The vulnerability of fish to stranding is a function of their size and behavioral response to changing flows, which depends on species, water temperature, time of year and time of day. Newly emerged fry are most vulnerable to stranding because of their limited swimming ability, their tendency to use the substrate for shelter and their preference for side channels and shallow river margins. As juveniles grow they tend to move to deeper, higher velocity water associated with main channel habitats where they are less susceptible to stranding. (Redd Dewatering and Fry Stranding Monitoring and Evaluation Plan for the Lower Yuba River, Jones and Stokes, January 2002)

While slow, gradual ramping rates are important in minimizing gravel bar stranding, isolation of juveniles in off-channel habitats may occur regardless of ramping rate because of favorable rearing conditions, the distance of these habitats to the main river, and an apparent reluctance of juveniles to move away from protective cover (Bradford et al. 1995, Higgins and Bradford 1996, Bradford 1997, Jones and Stokes 1999)

Previous DWR investigations on the Feather River demonstrate that flow fluctuations cause some stranding. In January 1997, DWR temporarily reduced flows from 1800 cfs to 1600 cfs in the Feather River below the

Thermalito Afterbay outlet. A subsequent survey found one pond with 47 juvenile salmon and four additional ponds that potentially had some stranding. A preliminary draft of the 2000-2001 season stranding survey calculated an estimated total of 2500 “spring-run sized” Chinook and 40 steelhead were stranded (DWR unpublished data).

There are two types of stranding, beach stranding and isolation basins.

General characteristics of beach stranding:
- very low slope
- suitable substrate
- physical size and shape (large enough for fish not to move off of)

General characteristics of isolation basin stranding:
- Most often occur in over bank areas
- A basin is a concave shaped lower elevation area that when inundated is a shallow area connected to the main water flow
- When flows are reduced to the point were the shallow water area is isolated from the main water flow, it becomes a stranding basin, which looks like a puddle or pond
- At the point the basin becomes inundated from the main flow, that is referred to as the inundation flow level
- Are less determined by ramping rates than beach stranding

Potential juvenile mortality from isolation basin fish stranding:
- Thermal stress
- Oxygen depletion
- Increased opportunity for predation
- Dewatering
- Competition for food
- Crowding

Flow fluctuation criteria were developed in response to the 2000 Biological Opinion from NMFS to minimize the effect of flow fluctuations on the two salmonid species downstream of the Lake Oroville reservoir (Study Plan: Steelhead and Spring-Run salmon Redd Dewatering and Juvenile Stranding in the Lower Feather River, DWR 2000). A stranding monitoring program was developed by DWR and approved by NMFS.

Oroville operations are currently working under flow fluctuation guidelines to minimize the potential for fish stranding. Flow reductions are regulated to 200 cfs/day for within bank flows. Under within-bank flow conditions, a flow reduction of 200 cfs is approximately equivalent to a 1” stage elevation change in the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet (personal communication, Ted Sommers). Flows reductions are regulated to 500 cfs/day for out of bank flow levels. Under out-of-bank flow conditions, a flow reduction of 500 cfs is approximately equivalent to 1” stage elevation change in the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet (personal communication, Ted Sommers).

Description of flow characteristics to channel confinement in the Feather River below the Thermalito Afterbay outlet above Honcut Creek (Study Plan: Steelhead and Spring-Run salmon Redd Dewatering and Juvenile Stranding in the Lower Feather River, DWR 2000). Flows less than 7000 cfs are contained within the active channel with some stranding potential identified in side channels and gravel bars. 7,000 – 17,000 cfs flows result in inundation of overbank areas and floodplain areas with stranding potential for isolation basins. Over 17,000 cfs flows in the Feather River from the fish barrier dam down to the Thermalito Afterbay outlet are flood control releases which have the ability to inundate the Oroville Wildlife Area and creates opportunities for potential stranding.

Greater than 90% of juvenile Chinook emigrate as post emergent fry, so only a small proportion of the juvenile Chinook rear in the Feather River with the majority of that activity occurring in the Low Flow Channel (DWR unpublished data). Only a few rearing steelhead have been documented in snorkel surveys (DWR unpublished data) with most rearing occurring in the Feather River from the fish barrier down to the Thermalito Afterbay outlet where stranding is not a significant factor due to the managed near constant 600 cfs flows.

Geographic Scope. The geographic area covered by the current stranding survey covers the Feather River from the Fish Barrier Dam down to the confluence with Honcut Creek. The area from Honcut Creek down to the confluence of the Sacramento River is not included in the current on-going stranding potential survey, but it will be evaluated to identify areas with the combinations of hydrologic cross section, substrate, and water velocities that may identify specific locations for additional representative stranding potential monitoring that may be included in subsequent surveys. Previous surveys by DWR indicate that very little rearing activity occurs below Honcut Creek (DWR unpublished data). The Oroville Wildlife Area (OWA) is also not covered under the current survey scope as the OWA only becomes susceptible to stranding potential flow fluctuations from flood control events.

Study Scope. Surveys will be conducted year round, on a daily basis, when flow fluctuation events occur as steelhead rear in the Feather River year round. Isolation basin type stranding will be the primary focus of this study.

Beach stranding will not be considered due to the following factors:

- This type of stranding is generally believed to be only a minor component of overall stranding potential
- A maximum of 1 inch change in stage elevation of the water is unlikely to produce any significant beach stranding
- Problems with predation by birds before a survey could be conducted which would frustrate any effort at accurate beach stranding survey results
- This type of stranding would occur in intragravel spaces and therefore be very difficult to quantify in any reliably quantitative manner

Stranding Potential Survey Methodology:
This study proposes to adopt the currently implemented and approved juvenile stranding survey being conducted as part of the response to the NMFS 2000 Biological Opinion. Modifications to the approved survey methodology will be proposed only to the extent required to satisfy specific study objectives so that the maximum continuity with the existing data can be preserved.

Existing Data Review

Literature and existing data review of historical flow fluctuations will be conducted to determine the historical frequency and ramping rates for evaluation against stranding survey data collected.

Survey Frequency

Daily of monitoring will be conducted for each flow reduction event increment of 200 cfs for flows less than 7,000 cfs and for 500 cfs reduction increments for flows between 7,001 and 17,000 cfs flows.

Sample Plan

Areas for stranding potential surveys have been pre-qualified from aerial photo interpretation and ground surveys. 12 isolation basins in the reach of the Feather River extending from the Thermalito Afterbay outlet to

Honcut Creek in the 1,000 cfs – 8,000 cfs flow ranges have been identified from the 2000-2001 season stranding survey (DWR unpublished data)

Aerial extent of isolation ponds will be quantified by delineating the stranding potential areas on a digital orthophoto map base of a known scale and calculating the area. This size measurement of the stranding basins will also be used to segment the stranding potential areas into size classes for representative sampling and monitoring. Existing sampling locations will be reviewed for size class and river reach (spatial distribution) representativeness.

Non-Stranding Potential Isolation Basin Differentiation

Ponds inundated by sub-surface flows will be identified during field surveys to correct for this potential error in the calculation of the total stranding potential area and total stranding enumeration estimates.

Stranding Enumeration Methods

Isolation basins sampling for fish stranding will include:

- Beach seining for ponds less than 1.2 meters deep and free of major obstructions
- Snorkel transect surveys for ponds deeper than 1.2 meters or with obstructions
- Eletro-fishing for ponds with turbid water and obstructions

Survey Records

Isolation basin data recorded in the Stranding Survey will include:

- Location/unique ID of isolation basin
- RTK GPS elevation of connection point of isolation basin or documentation of inundation flow level
- Average depth
- Distance to main channel
- Substrate
- Cover
- Area sampled
- Sample method
- Fish metrics

Fish Metrics

Data collected on fish sampled will include:

- Species
- Number of fish
- Size (mm FL) (up to 20 fish/pond for non-salmonids and up to 100 for salmonids) (adult stranding observed will be documented)

Fish sampled will be handled in accordance with the RST handling protocol documented in SP-F10, Task 4A.

Analysis. Evaluate SP-G2 cross section and substrate survey results from Honcut Creek to the confluence of the Sacramento River to identify any additional stranding potential areas to be selected for representative monitoring in the stranding potential surveys. Chinook fish size (mm FL) will be classed into “spring-run sized” and “fall-run sized” according to “Fisher Criteria” daily length table (Green, S. 1992) for Central Valley Chinook salmon. The population density of the sampled fish will be calculated by dividing the number of fish sampled per pond by the area sampled. The average density of fish stranding/per size and geographic reach will be calculated. The total stranding estimate for each size class will be calculated by multiplying the fish stranding density by the total isolation basin area for each size class and geographic reach. The total number of fish stranded per stranding monitoring survey will be calculated based on the sampled number of fish, the population density estimate, an extrapolation of total stranding estimation by applying the stranding density by size class average to the total area in each stranding potential size class. The amount of area of the isolation basins will be aggregated by the inundation flow level classification (either observed or calculated from inundation elevation vs. the stage discharge curve) by size class by geographic reach. The stranding by fish type will be reaggregated by flow range, by size class, by geographic reach to estimate the amount of stranding by type by flow range. This will provide potential insights into potential PM&E's and operating flow fluctuation guideline suggestions. The estimate of total stranding by fish type will be compared to salmonid emigration estimates from the rotary screw trap sampling to determine the relative significance of stranding to juvenile salmonids. If sufficient flow fluctuation ramping rate and resulting fish stranding data is available and suitable for an analysis, a correlation of ramping rate to fish size and life stage will be conducted. The results of this analysis could be utilized to evaluate ramping rate operating recommendations for various fish size and life stages.

Identify Potential PM&E's:
Potential preventative measures and enhancements will be evaluated and proposed for consideration. Potential proposed PM&E's could include:

- The modification of the connection of a basin to the main channel to reduce or eliminate basin stranding in those areas identified as contributing the most to the total amount of stranding.
- Ramping rate recommendations
- Flow fluctuation timing and range recommendations

Task 4—Evaluation of project effects on emigration of juvenile salmonids in the Feather River

Oroville facility operations influence the water temperature and flow in the Feather River downstream of the Fish Barrier Dam. Both water temperature and flow directly affect emigrating juvenile salmonids (USBR and DWR 2000). Because emigrating juvenile salmonids are influenced by water temperature and flow, and because water temperature and flow are influenced by project operations, an evaluation of potential project effects on emigration of juvenile salmonids requires that the relationships between water temperature/flow and juvenile salmonid emigration be thoroughly investigated.

Little data exists regarding the residence time of juvenile steelhead in the Feather River (DWR 2001). Juvenile steelhead are believed to spend one to three years in fresh water before migrating to the ocean (DWR and USBR 2000). DWR studies suggest that while many juvenile steelhead emigrate as fry soon after emerging from the gravel, some appear to rear for one to six months before emigrating (DWR 2001). In the Feather River, steelhead emigration principally occurs from June through September (DWR and USBR 2000). However, YOY steelhead have been observed in the river from mid-September to October, suggesting that some juveniles had not yet initiated downstream migration (DWR and USBR 2000).

Emigration data for Feather River juvenile spring-run sized Chinook is insufficient for estimation of a reliable emigration time frame (DWR 2001). Run time is reported to be highly variable (DWR 2001). Fall-run sized Chinook fry spend little time rearing in the Feather River, with emigration occurring shortly after hatching, primarily from December through June (DWR 2001). Most (>90%) fall-run sized Chinook emigrate as post-emergent fry, although a small number of Chinook may continue to rear in the Feather River throughout the summer (DWR 2001). Chinook are classified as fall-run sized or spring-run sized based on size at time data (Greene 1992).

Task 4A—Describe the relationship between flow and juvenile salmonid abundance and emigration patterns, and evaluate the potential project effects on salmonid juvenile emigration

Flow rates may directly influence the timing and other aspects of juvenile salmonid downstream migration. Flow rates may indirectly affect other environmental conditions, such as water temperature and turbidity, which in turn directly affects juvenile salmonids (DWR and USBR 2000). While other tasks evaluate the relationship between flow and rearing habitat (Task 3A) and flow and juvenile stranding (Task 3C), this subtask specifically investigates the relationship between flow and emigrant juvenile salmonid abundance and patterns.

Relationships between juvenile salmonid emigration and the timing, magnitude and frequency of flows have often been speculated. However, studies attempting to corroborate such relationships have been scant. One study conducted by DFG in the American River illustrated no direct correlation between peak spring flows and peak emigration of juvenile Chinook (PCWA and USBR 2001). In many instances, efforts to corroborate relationships between juvenile salmonid emigration and the timing, magnitude and frequency of flows have been inconclusive, often due to the insufficiency of available data.

In the Feather River, data on juvenile Chinook salmon abundance and emigration patterns have been obtained sporadically since 1955. Painter et al. (1977) used fyke nets to capture emigrating juvenile Chinook salmon at Live Oak between 1968 and 1973. DWR has been using rotary screw traps (RST) at Live Oak and Oroville since 1996 to monitor the abundance and timing of juvenile Chinook salmon emigration. Considering the short duration of the current DWR series of RST data and the scarcity and irregularity of surveys prior to 1996, no hypothesis relating flows, directly or indirectly, to juvenile salmonid abundance and emigration has been formally developed for the Feather River. Preliminary data indicate that neither temperature, flow, nor turbidity show strong correlation to initiation of juvenile outmigration. The proposed data collection effort is designed to build on existing data and to provide a continuous and consistent data record for analyzing effects on juvenile outmigration. In order to better characterize the relationship between flow and juvenile salmonid abundance and emigration, two specific actions are recommended. The first action includes a review of past data on juvenile salmonid abundance and emigration patterns, and the second action is the continuation of current DWR RST surveys.

Conceptual Framework. The flow regime associated with the ongoing operation of Oroville facilities may affect the abundance and emigration pattern of Feather River juvenile salmonids.

Review of Existing Data and Literature. The review of existing data involves the assembly, integration, and summary of data collected by previous efforts to characterize juvenile salmonid abundance and emigration in the Feather River. In addition to the summarization, this review requires evaluation of the data quality and the consistency of previous Feather River juvenile salmonid survey efforts. The purpose of evaluating past surveys is to use appropriate data from those surveys to develop an initial working hypothesis on the direct and indirect effects of flows on juvenile salmonid abundance and emigration.

Many methods have been proposed to study outmigrating juvenile salmonids on the Feather River including RSTs, trawls, fyke nets, and snorkel surveys. Although RSTs are currently in use, there are some disadvantages to using RSTs for enumeration of juvenile steelhead outmigrants in the Feather River. One disadvantage is that the number of juvenile outmigrant steelhead captured is not sufficient to allow for trap efficiency estimates for juvenile steelhead. This precludes development of a statistically valid method for determining a multiplier that could be applied to the catch for generation of an estimate of the total number of emigrating juvenile steelhead. Additionally, larger juveniles may avoid RSTs. When RSTs were run experimentally through August, few steelhead were captured (DWR, unpublished data). Trawls and fyke nets have been proposed as methods for enumerating outmigrating juvenile salmonids, but these methods have deficiencies as well. Trawls would not allow differentiation between migrating and rearing juveniles. Fyke nets do not reliably capture large fish and juveniles have been observed to swimming out of fyke traps (M. Meinz, pers. com.). Snorkel surveys are currently underway during the emigration period (March through August) and will be continued in Task 3A. Snorkel surveys may provide information regarding juvenile emigration timing and fish abundance and size. However, because the likelihood of observing a rearing fish, which is residing in he river, is much higher than the likelihood of observing an emigrating fish, which is transient, most snorkeling observations of juveniles are anticipated to be observations of rearing juveniles. Additional methods for estimating the number of outmigrant juvenile steelhead include inclined screen traps, incline plane traps, electric fish counters, and camera monitoring (for review see Newcomb and Coon 1997). Inclined screen traps have low capture efficiency and require a low head dam. Incline plane traps have extremely low capture efficiency, ranging from 0.023 to 0.024%. Both electric fish counters and camera monitoring require fish to pass through a small, constricted area. These techniques are best utilized on small streams or in rivers in which the fish are routed through a narrow corridor, such as a weir. Although each potential methodology has drawbacks, the combination of snorkel surveys and RST efforts has been suggested as the most useful combination of feasible methods that will allow continuity with existing data and provide complementary ways to assess juvenile outmigration.

One aim of this review is to provide insight regarding potential changes to current RST sampling protocol and experimental design and to suggest modifications for determining abundance of juvenile steelhead. Because there are deficiencies in the use of RSTs for enumerating juvenile steelhead, additional methodologies or changes to the existing methodology may be proposed to estimate juvenile steelhead. Examples of modifications that may be evaluated include adding wings to RSTs to aid in sampling margin-areas and rafting several RSTs together to improve trap efficiencies. The literature review may include reports of vertical and horizontal distribution of fish in the water column (to aid in determination of RST location) and a review of the behavior of juvenile towards different fishing devices (to aid in the design of RST wings). Additionally, the review will include an evaluation of the relative efficacy of nets and other fishing devices used in past surveys (e.g., Painter 1977) and published literature to provide reliable information on juvenile abundance and emigration. This portion of the review will serve to provide perspective on the compatibility of previously collected data. This review and recommendation task should be completed by June 2002.

Rotary Screw Trap Survey. The continuation of DWR RST surveys begun in 1996, intends to provide a long and consistent series of juvenile Chinook abundance and emigration data that will allow refinement and testing of the initial working hypotheses on the direct and indirect effects of flow on juvenile salmonid abundance and emigration. Details of the methodologies utilized in the RST surveys are provided in following paragraphs.

Two eight-foot rotary screw traps (RSTs) will be the main sampling devices used for the emigration survey. RSTs are sturdy, relatively easy to move within the stream, relatively easy to operate and maintain, capable of capturing fish without harm in fast-moving water, and able to sample continuously. An RST operates using a trapping cone lowered into flowing water, which strikes the baffles on the inside of the trapping cone, causing the cone to rotate. Fish will enter the upstream end of the rotating trapping cone, become trapped inside the trapping cone, and are carried rearward into a live box. One RST will be placed at approximately RM 60.1, one mile upstream of the Thermalito Afterbay outlet. The other RST will be placed near the town of Live Oak (approximately RM 42). Two RSTs are needed because operation of the Oroville Facilities results in two substantially different flow regimes. Flow in the reach of the Feather River from the Fish Barrier Dam to the Thermalito Afterbay outlet is usually maintained at about 600 cfs; the reach of the Feather River extending downstream of the Thermalito Afterbay outlet is subject to variable flows during emigration. Therefore, emigration cues and salmonid composition may differ in the two reaches.

The RST sites are selected based on the following criteria for installation, operation, and maintenance: (1) depth greater than six feet at minimum flow; (2) velocity greater than two feet per second at minimum flow; (3) suitable anchoring point(s); and (4) limited public access. During the time between the acceptance of this study plan and the initiation of the next juvenile emigration season, data from the previous mark-recapture RST surveys will be analyzed and the RST capture efficiencies will be calculated. If the RST capture efficiencies are extremely low, additional modifications to sampling protocol, such as installation of wings on the RSTs, may be recommended to improve the probability of recapture, and therefore improve the accuracy and precision of numeric estimation of juvenile emigrating Chinook.

The sampling devices will be fished continuously for approximately seven months (November through June), except whenever river conditions become unsafe due to floods, especially at Live Oak. Both RSTs will be serviced at least once a day, and more often when there is a high debris load. During servicing, trapped fish will be removed from the live box, identified, and counted. Fork length (to the nearest millimeter) will be measured for up to 50 individuals of each species. The fish will then be released back to the river, except for salmon retained for coded-wire tagging.

Chinook salmon individuals will be measured and inspected for characteristics such as presence of parr marks, silvery appearance, and deciduous scales to determine lifestage and degree of smolting. The following life stage designations will be used:

- Stage 1 = Yolk-Sac Fry (when yolk sac is clearly visible)
- Stage 2 = Fry (even when individual has parr marks but not fully zipped)
- Stage 3 = Parr (only when individual has clear parr marks and fully zipped)
- Stage 4 = Silvery Parr (when individual has fading parr marks and some scale loss)
- Stage 5 = Smolt (when parr marks are absent or extremely faded and there is noticeable scale loss)
- Stage 6 = Adult

A salmon tagging station will be set up at the Thermalito Afterbay outlet to tag juvenile Chinook salmon and steelhead produced in-channel with coded wire tags (CWT). Juvenile Chinook salmon and steelhead captured in the RSTs will be transported to the tagging station and implanted with a CWT half-tag (Northwest Marine Technology, Inc., Washington). The juveniles will be held overnight while a sub-sample is checked for tag shedding, and then released just downstream of the Live Oak boat ramp.

The screw trap sampling is designed to be nondestructive to fish. For all species, but especially for those listed under either the Federal or State Endangered Species Acts, efforts are made to minimize stress associated with collection, handling, processing and release of all captured fish. Techniques to minimize stress or loss include processing all salmonids and other listed species first, to minimize holding and handling time; wet hands and measuring boards to minimize loss of protective slime coat; subsample to determine length frequency distribution to minimize holding time and number of fish handled; and carefully anesthetizing salmonids and other listed species using MS-222, and after length and weight measurements are taken, allow the fish to recover before returning them to the river.

Other measurements collected daily at each RST will include water clarity (measured by secchi depth and a continuously logging tubidimeter at each RST), water temperature, the length of time the RST was fished during the sample period, the average number of trapping cone revolutions per minute, water velocity and the total number of trapping cone revolutions during the sampling period. These parameters should serve to ensure the data gathered in this study is compatible with data collected by other fish monitoring projects in the Sacramento River basin. Flow data will be obtained from DWR records of releases from the Thermalito Diversion Dam and the Thermalito Afterbay outlet.

RST efficiency will be evaluated using fish collected in the RSTs. Evaluations will be conducted using emigrants captured in their respective traps (i.e. emigrants trapped at Live Oak are only used for Live Oak trap efficiency evaluations). RST efficiency will be calculated during periods of peak emigration of juvenile Chinook salmon when sufficient numbers of juvenile salmonids are present to warrant trap efficiency estimation. Although the actual dates for which trap efficiency will be calculated will depend on observed number of juvenile salmonids in the RSTs, it is generally expected that peak emigration will occur from November 1 through April 15. Approximately 1000 marked fish (marked with dye such as Bismark Brown) will be transported roughly 1.75 kilometers upstream of each RST. The fish will be as uniformly distributed as possible. Care will be taken to ensure that only healthy fish (visual observations only) are released. RST catch will be monitored for recaptures for seven days after marked fish are released. Recapture will be monitored for seven days, as previous observations suggest that most recaptures occurred within three to seven days after release. Releases will be eight or more days apart, and efficiency tests are performed separately on a weekly basis (as possible).

Trap efficiency will be calculated using the method from previous DWR RST data to maintain continuity with the existing data sets. Trap efficiencies will be calculated by averaging two adjoining weeks of efficiency values to calculate daily trap efficiency and daily salmonid emigration past each trap. Efficiency values will only be applied to RST catch occurring during peak migration (as defined by observation but generally expected to occur between November 1 and April 15). Snorkel observations (DWR, unpublished data) and RST catch data indicate that, beginning in April, peak outmigration of juvenile Chinook salmon may have ended, and therefore trap efficiency values applied to subsequent days may be invalid. Trap efficiencies will be partitioned by week and compared to flow records. If there is a detectable relationship between flow and trap efficiency, the relationship will be described mathematically and may be used to estimate trap efficiency for weeks which have insufficient numbers of fish to perform mark-recapture estimates of trap efficiencies.

Collection of Available Flow Data. Flow data will come from DWR records of releases from Oroville Dam and Thermalito Outlet. These flow data have been used previously to ensure consistency with other fish monitoring projects in the Sacramento River system and will be used to maintain continuity with previous RST data.

Analyses. To characterize the relationship between flow and emigration, flow data and emigration estimates will be compared. Flow records will be obtained from DWR records corresponding to locations of the RSTs (see above). The information gained from the comparisons of flow and RST emigration estimates will be added to information gathered from the review and from previous RST surveys. Comparisons will be used to test initial hypotheses regarding potential flow-related effects on juvenile Chinook emigrations. The testing of these hypotheses will serve to evaluate potential project effects on juvenile salmonid emigration. Data gathered during this study will serve to recommend appropriate PM&E measures, if such measures are deemed necessary.

To provide continuity with prior DWR emigration estimates, an emigration index (*EI*) will be computed. The emigration index is a per-capita production estimate that will be used to compare Chinook production from year to year. The emigration index is calculated by dividing the emigration estimate (*E*) for the river by the estimated number of adult/grilse females determined by the fall escapement survey (*F*):

$$EI = \frac{E}{F}$$

The error associated with this estimate may be very large due to the error associated with the application of the trap efficiencies for the emigration estimate (see below) and the application of mark-recapture estimates for the escapement survey. The emigration index should not be taken as a definitive quantitative estimate due to the variability associated with efficiency estimates. The EI will serve as a comparison of the estimated number of juveniles resulting from the estimated number of spawners from one year to the next. The possibility of partitioning the EI by time units (weeks or months), juvenile size (fork length), or by juvenile life stage designation (fry, parr, smolt) will be investigated for use in making within-year comparisons.

The emigration estimate (E) will be obtained by expanding daily catch (C_d) by the average RST efficiency value (q_d) and then summing daily catch for the peak emigration period.

$$E = \sum_{d=\text{Dec.1}}^{\text{Apr.15}} \left(C_d \times q_d \right)$$

This estimate will be made for both the Thermalito Afterbay outlet RST and the Live Oak RST, as the different flow regimes in the river reaches may results in different trap efficiencies. In addition to a seasonal estimate, daily emigration estimates will be constructed by expanding the daily catch by the weekly trap efficiency. Monthly emigration estimates could be constructed by expanding the weekly catch by the weekly efficiency and summing the weekly data for one month. Measures of flow (daily average, max. daily, weekly average, and max. weekly) will be compared to daily or monthly emigration estimates to investigate the effects of flow on juvenile outmigration. Regression and or ANOVA are among the techniques that may be used to determine whether there is a detectable relationship between flow and outmigration.

Task 4B—Describe the relationship between water temperature and juvenile salmonid abundance and emigration patterns, and evaluate the potential project effects on salmonid juvenile emigration

Water temperatures affects growth, survival, abundance, distribution and emigration of juvenile salmonids. In order to describe the relationship between water temperature and juvenile salmonid abundance and emigration patterns, a literature review will be conducted, followed by a compilation of water temperature records relevant to the distribution of emigrant juveniles in the Feather River. The outputs of these two activities will then be used in the evaluation of the potential impact of the water temperature regime resulting from the operation of the Oroville facilities on the distribution and emigration of Feather River juvenile salmonids.

Conceptual Framework. The temperature regime associated with the ongoing operation of Oroville facilities may affect the abundance and emigration pattern of Feather River juvenile salmonids.

Review of Temperature Effects. An initial literature review will be conducted to obtain information from past emigration surveys, salmonid physiology studies, published literature, existing DFG and DWR reports, laboratory and field studies that empirically determine water temperatures for smolting and emigration, and other sources regarding water temperatures for smolting and emigration of Chinook salmon and steelhead. Studies that describe the upper limit of temperature tolerance and the optimal temperature range for juvenile smolting and emigration will be summarized. From these studies, a range of suitable water temperatures for smolting and emigration for each species will be determined.

Collection of Available Water Temperature Data. Historical water temperature records and water temperature model outputs from SP-W6—Project Effects on Temperature Regime will be processed for the subsequent evaluation of potential impacts of the water temperature regime resulting from the operation of the Oroville facilities on the distribution and emigration of Feather River juvenile salmonids.

Existing water temperature records may not be sufficient to construct historic water temperature time series for the areas relevant to the distribution of juvenile salmonids in the Feather River (Fish Barrier Dam to the confluence of the Sacramento River) and the months when the emigration juvenile salmonids from their Feather River rearing grounds occurs. Therefore, it is anticipated that much of the Feather River water temperature information utilized in this task will be derived from SP-W6—Project Effects on Temperature Regime. For example, the existing Feather River water temperature data collected at the Thermalito Afterbay outlet and compiled by SP-W6 Task 1A, as well as all new water temperature data collected and compiled by SP-W6 Task 1A for stations located downstream of the Thermalito Afterbay outlet will be utilized.

Analyses. The compiled water temperature information will be utilized to determine how often water temperatures in the Feather River are outside the range of suitable water temperatures for smolting and emigration (from above literature review), during the emigration period of steelhead and Chinook salmon. For each species, this comparison will provide information including the frequency with which water temperature exceeds recommended smolting and emigration temperature, and the extent to which water temperatures rise above the recommended temperature in the Feather River during the emigration period. This comparison will facilitate evaluation of the potential project effects on salmonid juvenile emigration and will serve to recommend appropriate PM&E measures, if necessary.

6.0 Results and Products/Deliverables

Results

Results will be organized following the task headings. Each task will include a narrative of the relevant findings as well as tables, figures and maps summarizing the key points.

Products/Deliverables

The anticipated maps, tables, graphical representation of reviewed data (e.g., charts, plots, and graphs), figures, and specific summary report elements include:

- Tables describing calculated flow indices (flow ratios) for the Sacramento and Feather River confluences and the Feather and Yuba River confluences, tables describing the calculated straying indices for the Sacramento and Feather Rivers and the Feather and Yuba Rives, plots of the monthly and annual straying indices as a function of the flow indices, and tables or figures presenting resulting goodness-of-fit tests. A summary including new predicted Feather River straying index values as a function of flow and a power analysis, if necessary, will be included (Task 1A);
- Tables describing calculated temperature indices (temperature ratios) for the Sacramento and Feather River confluences and the Feather and Yuba River confluences, tables describing the calculated straying indices for the Sacramento and Feather Rivers and the Feather and Yuba Rives, plots of the monthly and annual straying indices as a function of the water temperature indices, tables or figures presenting resulting goodness-of-fit tests, and a summary including new predicted Feather River straying index values as a function of water temperature (Task 1B);
- Tables or figures summarizing comparisons of Chinook escapement data to flow data and comparisons of adult steelhead returning to the Feather River Hatchery to flow data, results of statistical comparisons, and a summary describing the relationship between flow and upstream adult salmonid migration in the Feather River(Task 1C);
- Tables or figures summarizing water temperature ranges for fish biological performance, tables or figures summarizing water temperatures recorded in the Feather River, and a summary comparing the recommended water temperatures ranges extracted from the literature review to the water temperature data gathered for the Feather River (Task 1D);
- Tables, figures or maps recording the identified potential early-upmigrant adult Chinook salmon holding habitat, tables, figures or maps identifying pools chosen for sampling, tables or figures summarizing results of temperature profiling of potential holding pools, tables or figures summarizing cover and substrate characterization of pools, tables or figures summarizing results of radio-tagging data, tables or figures summarizing locations of fixed receiver stations and manual tracking frequency, tables or figures summarizing results of thermal archiving tagging, and a summary of the available holding habitat characteristics, the results of the radio tagging surveys, and the analysis described in the study plan (Task 1E);
- Tables or figures summarizing spawning and incubation habitat characterization from SP-G2 data including surface substrate quality, velocity, width, depth and length of spawning riffles, and gradation curves, a comparison to past studies, and a summary detailing the spatial distribution of spawning salmonids as it relates to relevant population characteristics (Task 2A);

- Tables or figures comparing flows at the reach of the Feather River extending from the Fish Barrier Dam to the Thermalito Afterbay outlet and below Thermalito Afterbay for each specified month and fish species, a summary evaluating the potential project effects on salmonids spawning and rearing based on flow comparison, a summary detailing weekly Chinook salmon spawning escapement survey results including assessments of the distribution of naturally spawning populations in the Feather River, the contribution of hatchery-reared fish from other river systems (in conjunction with SP-F9), annual and weekly sex ratio changes, spawned females, and pre-spawning mortality calculations; A summary of steelhead redd surveys; Maps, tables or figures detailing the temporal and geographical distribution of hatchery and wild adult salmonid spawners; data supporting PHABSIM validation (Task 2B);
- Tables or figures illustrating when water temperatures have exceeded recommended temperatures for relevant fish during specified lifestages, a summary detailing the application of water temperature data to statistical analysis relating water temperature input to early lifestage survival and adult spawning distributions, and figures summarizing results of the analysis (Task 2C);
- A summary report detailing the methodologies and results of the redd dewatering survey, including the calculated redd loss as a proportion of the total redds in the river (if redd loss is determined to occur) at various flows. This information will then be used in conjunction with a Feather River flow model to evaluate how project operations effects on stage/discharge potentially impact dewatered redds on a temporal and spatial basis (Task 2D);

A summary report detailing the methodologies and results of the broad-scale, intermediate-scale, and fine-scale snorkel survey including the number of fish, size of fish (fork length) by species, habitat-type utilized, substrate, water temperature, water depth, focal-point velocity, cover, and hydro-geomorphic unit; Tables and figures summarizing the length-frequency distributions and other capture results obtained from biweekly seining activities including weight of fish, size of fish (fork length), recapture rates and species-specific growth rates; Habitat characterization for rearing juvenile anadromous salmonids will be developed following the identification of temporal distribution and juvenile habitat characterization (Task 3A);

- Species-specific summary tables showing the critical temperature ranges and resulting effects will be determined through a literature review, these will be compared to water temperature tolerances observed through the enclosure experiment and the seining experiment; Tables and figures summarizing the results of each species-specific enclosure study and a summary report including specified statistical analysis designed to determine whether differences observed can be attributed to water temperature; Tables or figures summarizing biweekly seining results including the number of steelhead caught, size of the fish (fork length) and recapture rates as a means of investigating wild steelhead site-fidelity and growth. (Task 3B);
- Maps identifying potential ponding areas, tables or figures summarizing results of the stranding ground survey and beach seining efforts, tables or figures detailing calculations required to arrive at estimates of numbers of stranded juveniles by flow type, tables or figures showing emigration estimates, and a summary report describing stranding losses relative to the total juvenile population (if such stranding losses are determined to occur), proposal for potential preventative measures and enhancements (Task 3C);
- Tables or figures summarizing previously gathered data, data generated during the RST surveys, tables or figures summarizing results of the CWT efforts, tables or figures detailing emigration estimates and emigration index estimates; A summary report will include a review of published literature relating to

current RST sampling protocol and experimental design, fish distribution patterns in the water column, juvenile fish behavior towards various fishing devices, net efficacy as well as an evaluation of previously collected data and the development of an initial working hypotheses regarding the direct and indirect effects of the timing, magnitude and frequency of flows on juvenile salmonid abundance and emigration (Task 4A); and

- Tables summarizing optimal temperatures for juvenile smolting and emigration, figures illustrating the timing and frequency with which water temperatures exceed recommended values during the emigration period in the Feather River flow various flow scenarios and a review of past studies to determine a range of suitable water temperatures for smolting and emigration for each species (Take 4B).

Some of the tasks listed above include an interim report in addition to the final report. See section 8.0 Schedule for a detailed description of deadlines for literature reviews, interim reports, and final reports. The study plan summary report will include:

- Executive Summary
- Table of Contents
- List of Tables
- List of Figures
- Introduction
- Narratives of relevant findings by task (specific elements to be included are listed for each subtask above)
- Methodology
- Discussion addressing most relevant questions (see above) and indicating any complications/data concerns
- Conclusions related to study plan goals and objectives
- References
- Appendices

7.0 Coordination and Implementation Strategy

Coordination with Other Resource Areas/Studies

Completion of this study plan will require information from other resource study plans being prepared for the Oroville Facilities FERC Relicensing Project including engineering and operations (project operations and hydrologic and water temperature modeling results), geomorphology (river channel characterization), as well as other fisheries studies. It is noted that further coordination among study plans is currently underway to ensure consistency and efficiency in obtaining needed information.

Information and data gathered or results generated by the following fisheries studies will be utilized by SP-F10 to study potential project effects on salmonids in the Feather River below the Fish Barrier Dam:

- SP-F1-Evaluation of Project Effects on Non-fish Aquatic Resources

SP-F1 will provide macroinvertebrate sampling at enclosure locations in support of Task 3B if SP-F1 institutes a regular sampling procedure.

- SP-F9—Effects of the Feather River Hatchery on Naturally Spawning Salmonids

SP-F10 will obtain information regarding FRFH CWT returns from SP-F9, including information from contacts with the FRFH, queries to the CWT database kept by the Regional Mark Information Center, results of the CWT tag "collection blitz", and straying indices.

Other Environmental Work Group Study Plans

- SP-G2—Effects of Project Operations on Geomorphic Processes Downstream of Oroville Dam

In order to maximize cost-effectiveness, SP-G2 will provide SP-F10 with required geomorphic information regarding the Feather River downstream of the Fish Barrier Dam. Fieldwork completed in plan SP-G2 will support habitat characterization efforts in SP-F10. Data obtained from SP-G2 for the purpose of habitat characterization will include measurements of geomorphic parameters, substrate characterization, spawning gravel quality assessment, vegetation and canopy percentage, and assessment of woody debris and cover. Specific information and methodologies for obtaining these data to fulfill fisheries needs are given below. Geomorphic parameters including channel width, depth, cross-section, hydraulic radius, and roughness will be collected as specified in SP-G2. Substrate will be characterized in each habitat type occurring at each cross-section using both the Wolman pebble count method and gravel sieving as specified in Tasks 2 and 3 of SP-G2. Substrate characterization will include particle size down to 0.1 mm in diameter. Following substrate characterization, gradation curves will be produced by SP-G2. These curves will illustrate the grain-size cumulative and percent distribution and will be useful for assessing the suitability of spawning habitat. Spawning gravel quality will be visually assessed to describe gravel shape and embeddedness using the method used by SCE during relicensing of the Big Creek Hydroelectric Facilities. This assessment will occur during Wolman sampling and gravel sieving (Task 2 and 3, SP-G2). The quality of spawning gravel will be determined based on both angularity and embeddedness. Gravel of high spawning suitability is highly rounded, with little sand and fines and low embeddedness. Spawning gravel is considered of low quality if it is angular or if it is highly embedded with a high proportion of sand, regardless of angularity. The scoring criteria for spawning gravel quality are listed below:

Spawning Quality Rating	Description of Substrate
Excellent	Round-shaped spawning gravels loose in substrate.
Good	Round-shaped spawning gravels slightly embedded in substrate *or* moderately jagged-shaped spawning gravels loose in substrate.
Fair	Round-shaped spawning gravels embedded in substrate *or* moderately jagged-shaped spawning gravels slightly embedded in substrate.
Poor	Round-shaped *or* jagged-shaped spawning gravels deeply embedded in substrate.

Cover will be assessed by SP-G2 using a classification system currently in use by DWR. This cover classification system is described below:

Cover code	Cover description
A	No apparent cover

B	Small to medium instream objects/woody debris (<31 cm or 1 ft. in diameter)
C	Large instream objects/woody debris (>31 cm or 1 ft. in diameter)
D	Overhead objects
E	Submerged aquatic vegetation
F	Undercut bank

The dominant cover type will be noted. Additionally, if the dominant cover type is large instream woody debris (Code C), the number of total pieces of wood in or intersecting the active stream channel will be counted and recorded. Wood will be counted if greater than one-third of the length of each piece of wood is situated within the stream channel. Each piece of wood satisfying these criteria found in debris jams will be counted and recorded.

- SP-T4-Biodiversity, Vegetation Communities and Wildlife Habitat Mapping

SP-T4 will catalogue riparian vegetation for WHR mapping and will collapse the WHR classes into grasses, shrubs, bushes, and trees for use in SP-F10. SP-T4 will also provide SP-F10 with information regarding the amount of inundated littoral vegetation including assessment of the amount and location of inundated aquatic vegetation. Information collected from these surveys will be entered into GIS for map production, calculation of areas at different elevations, and calculation of habitat characteristics.

- SP-W1-Project Effects on Water Quality Designated Beneficial Uses for Surface Water

SP-F10 will obtain dissolved oxygen measurements in deep pools from SP-W1. Additionally, SP-W1 will compare water quality conditions to criteria established for freshwater aquatic life under Task 2 of SP-W1 and will report exceedances for impact analysis by SP-F10.

- SP-W6-Project Effects on Temperature Regime

SP-W6 will provide SP-F10 with data from *in situ* temperature loggers and vertical thermal profiles for use in tasks evaluating the effects of water temperature on various salmonid lifestages and physiological considerations.

- SP-R13-Recreation Surveys

Task 3 of SP-R13 will provide Task 2B of SP-F10 with creel survey information regarding angler efforts, catch, and observations.

<u>Engineering and Operations Work Group Study Plans</u>

The descriptions and evaluations of study area characteristics will incorporate the results from hydrologic and water temperature modeling completed for the project. Anticipated specific information to be obtained includes daily and monthly flow in the Feather River; and daily and monthly mean water temperatures in the Feather River. Engineering and operations plans and models utilized by SP-F10 include those described in SP-E1.1-Statewide Operations Model Development, SP-E1.2-Local Operations Model Development, SP-E1.5-Feather River Temperature Model Development, SP-E1.6-Feather River Flow-State Model

Development, and SP-E6-Downstream Extent of Reasonable Control of Feather River Temperature by Oroville-Thermalito.

Information and data gathered, or results generated by this study plan (SP-F10) will be provided for use in the study of project effects in the following study plans:

- SP-F2—Effects of Project Operations on Fish Diseases

SP-F10 will provide characterization of fish, lifestages and habitat, as well as results regarding project effects on salmonid habitat quantity and quality, which will be utilized in SP-F2. Additionally, SP-F10 will provide SP-F2 with the spatial and temporal distribution data for Chinook salmon and steelhead lifestages (e.g., rearing, and emigration) in the Feather River.

- SP-F3.1—Evaluation of Project Effects on Resident Fish and Their Habitat Within Lake Oroville, the Thermalito Complex, and Upstream Areas Within Project Boundaries

SP-F10 may provide, to the extent applicable, lifestage characteristics and habitat requirements for adult and juvenile resident salmonids for use in SP-F3.1.

- SP-F3.2—Evaluation of Project Effects on Non-Salmonid Fish and their Habitat in the Feather River Downstream of the Fish Barrier Dam

Information developed in SP-F10 including lifestage characteristics and habitat requirements for adult and juvenile salmonids may be used, to the extent applicable, for similar characterization of adult and juvenile resident salmonids and their habitat described in SP-F3.2.

- SP-F4—Evaluation of Project Effects on Passage of Fish Upstream of Lake Oroville

The Feather River salmonid life history and habitat requirements information compiled in SP-F10 may be used, as appropriate, in Task 1 of SP-F4. In addition, habitat suitability criteria information from SP-F10 will be reviewed for its applicability to Lake Oroville and upper Feather River tributary resident salmonids and their habitat and, as relevant, incorporated into SP-F4.

- SP-F5—Project Effects of FERC Project Fisheries Management Plans on a Balanced Fishery of Resident and Fish and Their Habitat

SP-F5 will utilize the Feather River salmonid life history and habitat requirements information compiled in SP-F10.

- SP-F8—Transfer of Energy and Nutrients by Fish Migrations

SP-F10 will provide the information to SP-F8 on Feather River salmonid life history and habitat requirements. SP-F8 also will utilize information on potential sources of mortality for salmonid spawning, rearing, and juvenile emigration supplied by SP-F10.

- SP-F13—Project Effects on California and Federal Special Status Fish Species

SP-F10 will provide SP-F13 with salmonid life histories, habitat requirements, and potential project effects related to special status fish species.

- SP-F15—Evaluation of the Feasibility to Provide Passage for Salmonids Past Oroville Facility Dams

Information on the Feather River salmonid life history and habitat requirements compiled in SP-F10 will be used in Phase1 of SP-F15. Graphical representations of the lifestage periodicity also will be obtained from SP-F10. SP-F10 will provide information regarding habitat suitability characteristics of Chinook salmon and steelhead including adult upstream migration (timing, and prevalent water temperature and flow conditions), adult holding habitat (habitat availability, water temperature, holding pool or stream characteristics), spawning (habitat availability and suitability, abundance and distribution, timing, and factors affecting timing and success such as substrate conditions and water temperatures), early development (factors affecting embryo incubation survival through emergence), juvenile rearing (habitat availability and utilization, distribution and abundance, water temperature, substrate characteristics, refuges, shade, cover, food availability, predation, stranding), and juvenile out-migration and movements (timing, prevalent flow, water temperature and other abiotic conditions).

- SP-F16—Evaluation of Project Effects on Instream Flows and Fish Habitat

The Feather River salmonid life history and habitat requirements information compiled for SP-F10 will be used to supplement information for the evaluation of project effects on instream flows and fish habitat described in SP-F16. Additionally, SP-F10 will provide empirical evidence to validate the output of the PHABSIM model.

- SP-F21—Project Effects on Predation of Feather River Juvenile Salmonids

SP-F10 will provide the life history and habitat requirements information for salmonids in the Feather River, including abundance and distribution of juvenile salmonids for use in SP-F21. This information will be compared to the abundance and seasonal and geographic distribution of predators of salmonids that occur in the SP-F21 study area to determine if operational characteristics of the Oroville Facilities contribute to increased or unnatural levels of predation.

Issues, Concerns, Comments Tracking and/or Regulatory Compliance Requirements

The following table lists the issue number and summarizes the elements of the issue statement addressed by this study plan. Several of the issues, or certain elements of individual issues, may be addressed in other study plans. The master comment tracking database provides an indication of how each comment is handled. This study fully or partially addresses the following Stakeholder issues:

Stakeholder issues fully addressed by SP-F10 Evaluation of Project Effects on Salmonids and their Habitat in the Feather River Below the Fish Barrier Dam

Issue	Description
FE32	Ongoing studies in the lower Feather River include adult and juvenile steelhead snorkel surveys and a habitat inventory, beach seine surveys to determine the temporal and spatial rearing extent of juvenile steelhead and salmon, rotary screw trap sampling of Chinook salmon to monitor the timing and number of emigrants, Chinook egg survival studies, particularly in the low-flow channel, Chinook spawning escapement surveys, redd de-watering and juvenile surveys in the Lower Reach, effects of water temperatures on juvenile steelhead rearing, steelhead creel surveys to gather adult steelhead life history data, and invertebrate research
FE35	Is riparian vegetative cover in the low-flow section and in the river downstream of Thermalito Afterbay adequate under present flow conditions for rearing steelhead and fall, late-fall, and spring-run Chinook salmon
FE37	Under existing conditions, are there adequate amounts of suitable gravel for salmonid spawning in the low-flow section and in the river downstream of Thermalito Afterbay
FE45	Evaluate salmon numbers
FE53	Are the present Project-related flow ramping/fluctuation restraints adequately protecting rearing salmonid species from being stranded in the low-flow section and in the river downstream of Thermalito Afterbay
FE56	The Feather River's low-flow reach has historically provided spawning habitat for a cold-water fishery. How have reduced flows to this stream reach affected water temperature and gravel substrate necessary for successful salmonid reproduction?
WE29	Does the increase in river water temperature that results from warmer Thermalito Afterbay releases during the spring and early summer months affect survival of salmonid species outmigrating from the Feather and Yuba rivers

Source: NEPA Scoping Document 1 and CEQA Notice of Preparation, DWR 2001

Stakeholder issues partially addressed by SP-F10 Evaluation of Project Effects on Salmonids and their Habitat in the Feather River Below the Fish Barrier Dam

Issue	Description
FE41	Early on and clearly identify flow rates and temperature requirements downstream of the dam and is also addressed in SP-F16
FE44	Increase emphasis on steelhead protection and habitat and less on salmon
FE46	Clearly identify species, flow rates and temperature requirements downstream of the dam and is also addressed in SP-F16
FE54	Are the present Project related flow ramping/fluctuation restraints adequately protecting Salmonid redds and juveniles, conserving their habitat and forage, and spawning gravel from being scoured out from the low-flow section and from the river downstream of Thermalito Afterbay and is also addressed in SP-G2
FE86	Adequacy of current ramping rate to protect anadromous salmonids and conserve their habitats and forage. This includes providing a range of schedule of flows necessary to optimize habitat, stable flows during spawning and incubation in gravel forms, flows necessary to ensure redd replacement in viable areas, and flows necessary for channel forming processes, riparian habitat protection and maintenance of forage communities. This also includes impacts of flood control or other Project structures or operations that act to displace individuals or their forage or destabilizes, scours, or degrades habitat and is also addressed in SP-G2, T4, and E&O
FE89	Impact of Project structures and operations on water quality conditions necessary to sustain anadromous salmonids and their habitats and is also addressed in SP-W1
FE90	Adequacy of current Project operating regimes and structures to optimize water quality conditions for anadromous salmonids and their habitats and is also addressed in SP-W1
FE91	Current condition of habitat potentially impacted by Project and alternatives to conserve or enhance anadromous salmonids and is also addressed in SP-F16

Issue	Description
FE95	The lower Feather River provides habitat to support a variety of anadromous fish species including Chinook salmon, steelhead, striped bass, American shad, and sturgeon. Potential changes in license conditions could adversely impact habitat supporting these species. Habitat investigations should evaluate the existing quality and quantity of habitat and determine alternative improvements for the various life history needs of anadromous species including flow, water temperature, instream and riparian cover, substrate and spatial area and is also addressed in SP-F16 and F3.2
FE97	The habitat for fishes in the lower Feather River is affected by the flow releases from the Project. Seasonal timing, volume, and rate of release all have an affect on fish habitat conditions. Potential changes in license conditions for flow releases could adversely affect habitat conditions for one or more fish species. Fishery investigations should examine the adequacy of flows for maintaining all life history needs for anadromous and resident species. There should be evaluation of potential for flow improvements in the low-flow section. Fishery investigations should be sufficient to determine how best to meet the combined needs of the various anadromous and resident fish species and is also addressed in SP-F16 and F3.2
GE4	Under existing conditions, are bankfull flows frequent enough to maintain channel morphology, sediment transport, habitat diversity and adequate gravels for salmonid spawning and rearing in the low-flow section and in the river downstream of Thermalito Afterbay and is also addressed in SP-G2
GE5	Under existing conditions, are the moderate winter floods and bankfull flows adequately recruiting the amount of large woody debris needed to maintain adequate salmonid rearing habitat in the low-flow section and in the river downstream of Thermalito Afterbay and is also addressed in SP-G2 and T4
GE23	Releases that reflect nature cycles benefit biological cycles – how have changes in seasonal release patterns affected fish and their habitat and is also addressed in SP-F16
W10	Effects of existing and future water releases and operations on water temperatures in the low-flow section of the river and downstream the quality and availability of habitat for salmonids and is also addressed in SP-F16
WE28	Does the increase in river water temperature that results from warmer Thermalito Afterbay releases during the spring, summer, and fall months limit the amount of suitable steelhead and salmon habitat in the river downstream of Thermalito Afterbay and is also addressed in SP-F16
WE54	Impact of Project structures and operations on water quality conditions necessary to sustain anadromous salmonids and their habitat. Adequacy of current Project operating regimes and structures to optimize water quality conditions for anadromous salmonids and their habitats and is also addressed in SP-W1

Source: NEPA Scoping Document 1 and CEQA Notice of Preparation, DWR 2001

8.0 Study Schedule

	Timing/Deadlines			
Task	**Field data collection occurring in SP-F10**	**Analysis**	**Interim Report**	**Final Report**
1A	N/A	Literature Review/Analysis to be completed 6 months after completion of the SP-F9 tag "collection blitz"	N/A	2 months following the completion of analysis
1B	N/A	Literature Review/Analysis to be finished 6 months following completion of relevant SP-F9 task	N/A	2 months following the completion of analysis
1C	N/A	Analysis to be completed 4 months following implementation of the SP-F10	N/A	Analysis and Report finished 6 months following implementation of SP-F10
1D	N/A	Literature Review/Analysis to be completed 6 months following 1st year of SP-W6 data collection	N/A	2 months following the completion of analysis
1E	Characterization of holding pool habitat June – October 2002 March – October 2003	December 2002 - Analysis completed	February 2003 - Report describing results of 1st field season characterizing holding habitat characteristics	January 2004 – Final Report
	Set up of Radio Tag Monitoring Station - 3 weeks prior to initiation of tagging			
	Radio tag adult Chinook – April-June 2003			
	Adult Chinook manual radio tag monitoring – April – October 2003	December 2002 - Analysis completed		

Timing/Deadlines				
Task	**Field data collection occurring in SP-F10**	**Analysis**	**Interim Report**	**Final Report**
2A	N/A	Literature review describing relationship between incubation/emergence and grain-size distribution, armoring indices for other central valley rivers plus analysis to be completed 6 months after SP-G2's completion of all relevant fieldwork	N/A	2 months following the completion of analysis
2B			October 2002 – Review and evaluation of steelhead spawning survey methodology	January 2004 – Final report to include 2nd data collection and all required analysis
	Carcass survey September December 2002 September December 2003	May 2003 carcass survey results and analysis, steelhead redd survey analysis, and superimposition index analysis completed	June 2003 – Interim report including analysis of 1st year of field data plus reviews and evaluations of existing data	
	Redd survey January – March 2003			
2C	N/A	Literature Review/Analysis to be completed 6 months following 1st year of SP-W6 data and relevant SP-G2 data collection	N/A	2 months following the completion of analysis
2D	Redd dewatering January – March 2002 October – March 2003 (if necessary)	May 2003 – Interim data analysis completed	July 2003 – Interim report completed	January 2004 – Final report to include results of 2003 survey between October to December
3A	Broad Scale June 2002 Snorkel survey March – August 2002 (Data entry: March – Sept 2002) Snorkel survey March – August 2003	October 2002 – Draft review of fish distribution, abundance and habitat characterization data; Interim data analysis completed	December 2002 – Interim report including review and data analysis to be completed	December 2003 – Final Report including 2nd year of data collection
	Timing/Deadlines			

Task	Field data collection occurring in SP-F10	Analysis	Interim Report	Final Report
3B	Enclosure study June-August 2002	March 2003 - Analysis completed	N/A	May 2003 - Final Report including literature review and data analysis
3C	Stranding survey Year-round 2002-2003	March 2003- Interim data analysis completed	May 2003- Interim Report completed	January 2004 - Final Report including 2nd year of data completed
4A			July 2002- Review of existing data and literature completed	October 2003 - Final Report completed;
	RST sampling Nov 2002-June 2003	August 2003 – Analysis completed	N/A	
4B	RST sampling Nov 2002-June 2003	August 2003- Analysis completed	N/A	October 2003 - Final Report

Note: an interim report is not generally required for tasks with one year of data collection.

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